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To the Readers

Editor-in-Chief

Prof. Metodi Teoharov

Dear readers of Bulgarian Journal of Soil Science,

Dear colleagues,

The third year of the Bulgarian Journal of Soil Science reaches every corner of the planet, thanks to the active work of the editorial staff and the well-prepared articles of the authors. The journal continued to print topical developments in the field of soil and agrarian science, ecology and environmental conservation. His subject matter was expanded with new headings - Soil Science and Society, Science and Education and etc. On his pages readers could found questions and problems related to the historical soil science, tropical soil science, environment, soil genesis, agrochemistry and soil fertility, meliorations and sustainable management of soil resources, radioecology and microelement composition of soils, parameters of soil characteristics, and etc. We will be grateful to the authors and the readers if they suggest new ideas or enrich the contents of the journal with relevant topics.

The aim is to help different institutions for the sustainable management of land and soil resources in the light of the global and European framework directives adopted after 2015 for soil protection. For us, it is extremely important to give the public a broad voice on the importance and conservation of soils as a unique natural and hard-to-recoverable, and in many cases non-recoverable, resources for the need to introduce new methods and technologies for the restoration of polluted, damaged and degraded soils and to mitigate climatic changes on Earth. The progressive degradation processes under the influence of anthropogenic and technogenic factors occupy threatening proportions. It is our duty, as researchers and environmentalists, to support national institutions and societies through the achievements of soil, agrarian and environmental sciences.

Last year the Bulgarian Journal of Soil Science received a high rank evaluations and journal is indexed in different scientific databases such as - SJIFactor, ResearchBib, CABI, NACID, Citefactor, OAJI, IIJIF, SIS and etc.

I would like to express my special thanks to all authors for their contribution and responsibility and good cooperation in our work.

Prof. Metodi Teoharov
Editor-in-chief of the Bulgarian Journal of Soil Science

Chemical Composition of Soil Solutions of Technosols from a Coal Mine Region in South-Eastern Europe.

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Abstract

The cationic and anionic composition, i.e. K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, phosphates, SO_4^{2-} and dissolved organic carbon (DOC) in soil solutions of Technogenic soils (Technosols) from the area of Maritsa-Iztok coal mine basin in Bulgaria was analyzed and links with overburden strata were discussed. Two sites are located at the Mednikarovo village with humus and non- humus reclamation under grass vegetation. The other two are situated near the village of Obruchishte (non-vegetated and pine-vegetated). The sites differ in their textural composition, physico-chemical and hydro-physical properties. It was found that major cations and anions in the soil solutions at Mednikarovo site did not exceed the maximum permissible concentration limits (MPCL) for drinking water, while in solutions from the Obruchishte Technosols, composed of black clays intermixed with coal ash maximum permissible concentrations of sulphate (250 $mg.l^{-1}$), phosphate (0.5 $mg.l^{-1}$), calcium (150 $mg.l^{-1}$) and magnesium (80 $mg.l^{-1}$) were exceeded and may pose a threat to contamination of surface and sub-surface water of reclaimed soils.

Key words: chemical composition, soil solution, technogenic soils, reclamation

Introduction

The consumption of solid fuels is progressively increasing, especially at opencast mining due to its economic efficiency (Zhivkova et al., 2003). While in developed countries their part is significantly smaller due to the use of other alternative sources, in developing countries these are the main energy source (Chen et al., 2013). The opencast mining impacts all environmental components. Globally, it is estimated that huge land territories have been destroyed by mining activities, which is the cause of serious negative effects on the landscape and relief, hydrosphere, atmosphere, soils, biodiversity, geo-ecological disasters, etc. (Ghose 2005, Sheoran et al. 2010, Zhivkova et al., 2003., Zheleva 2004, Wong 2003). Therefore, the reclamation of lands affected by mining activities should be an integral part of the whole process through the implementation of effective rehabilitation strategies (Ghose 1989). The deficiency of topsoil is identified as a main problem during rehabilitation because of poor reclamation practices and low content of organic matter in these areas. Sustainable land management will minimize the coal mining impacts on ecosystems and the preservation ecological diversity (Kavamura and Esposito, 2010, Lone et al., 2008, Singh et al., 2002).

The change of environmental factors has a significant effect on all the components in the ecosystem. Technogenic, anthropogenic, etc. impacts on soil have a significant influence on the liquid phase, i.e. the soil solution where all the processes of transformation, synthesis and degradation of organic and mineral substances takes place. Many authors (Christou et al., 2005, Smethurst 2000) point out the role of soil solution in soil formation and plant nutrition. Many researchers have highlighted the needs to study soil solution chemical composition as a very sensitive and dynamic component for assessment and analysis of chemical processes in soil under the influence of various factors (Johnson et al., 2000, Simeonova et al., 2017, Stoicheva et al., 2001, Wolt.,1994).

The aim of this study is to estimate the contents of macroelements (K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, phosphates, SO_4^{2-}) and DOC in soil solutions obtained from Technosols varying in reclamation process from the area of Maritsa Iztok coal mines.

Materials and Methods

The study was carried out at four plots, two of them were near Mednikarovo village, and were subject to humus and non-humus reclamation and the other two at Obruchishte village from the area of Maritsa-Iztok coal mines in Bulgaria (Atanassova et al., 2018). The experimental plots from the area of Obruchishte are located under pine forest (*P. nigra*) and were created more than 30 years ago, and consisted of loam-textured Pliocene overburden sediments from the nearby open-cast mine. Areas of ~200 m^2 non-vegetated plots amongst pine –vegetated areas were found. At the non-vegetated site of Obruchishte, soils were of sandy loam texture mixed with degraded lignitic particles and coal ash, and of sandy clay (0-5 cm) and clay texture at 10-20 cm at the pine vegetated site (Atanassova et al., 2018).

At Mednikarovo site the investigated soils were: humus layer-reclaimed soil of clay loam texture and non-humus reclaimed soil of sandy loam texture. The surface horizon with was translocated humus horizon of natural Vertisol occupying the territory prior to mining. The sub-layers of ~2 m are composed of yellow and green clays comprising the overburden sediments of the stratigraphic profile and possessing suitable physico-chemical characteristics (pH ~7, Atanassova et al., 2018a,b). Cation exchange capacity (CEC) was assessed as sum of titratable acidity (pH 8.2) and extractable Ca, by saturation with K malate at pH 8.2 (Ganev and Arsova 1980).

At the four sites samples were taken from grids Δ2 m, ~ 40 m^2 and sampling was at two depths where water repellency was demonstrated on the field 0-5 (10) cm and at 10-20 cm. The soil solutions were obtained by the following method: in soil water ratio 1:5, shaking for 1 hour, centrifuging and filtering through 0.45 μm acetate cellulose filter (Katoh et al., 2012). Anions in the soil solution (Cl^-, NO_3^-, SO_4^{2-}, phosphates, including dissolved organic carbon (DOC) were analysed with Spectroquant tests, Merck Millipore (PHARO 100). Cationic composition of soil solution was determined by AAS (Perkin Elmer). For the control of chemical indicators of soil solutions, Regulation No 9 of 2001 on the quality of water intended for drinking and domestic purposes has been used.

Results and Discussion

Data in the table show that studied sites are considerably different in physico-chemical properties. For the different sites the pH values varied significantly from strongly acid to neutral (3.0 to 7.20).

The high acidity at the non-vegetated site in Obruchishte is a result of the weathering of black clays present in the overburden layers. The electrical conductivity of the study sites in Obruchishte was significantly higher than in the soils from Mednikarovo (Table 1), due the higher ionic strength of the solution (mostly sulfates, Atanassova et al., 2018a,b). The CEC is the highest at Obruchishte site (non vegetated (60,7-75,0 cmol.kg^{-1}) and is the lowest in Mednikarovo non-humus reclamation (29,4-29,8 cmol.kg^{-1}). The sorption capacity depends on the mechanical composition, the organic matter content and the type of clay minerals which formed the finely dispersed part of the soil.

Table 1. *Physico-chemical properties of the studied sites*

Variants	Depth. cm	pH /H_2O/	EC mS/cm	CEC 8.2	CEC_{CA}	CEC_A	Al	Ca	Mg
				cmol$_c$.kg^{-1}					
		Mednikarovo. humus reclamation							
1/1	0-10	6.80	0.32	56.3	46.5	9.8	0.0	42.0	6.1
1/1	10-20	6.80	0.14	56.5	46.7	9.8	0.0	42.0	6.1
2/2	0-10	6.90	0.04	56.1	46.5	9.6	0.0	42.4	6.0
2/2	10-20	6.90	0.04	56.2	46.4	9.8	0.0	42.5	6.1
1/3	0-10	6.90	0.06	56.4	46.8	9.6	0.0	42.5	6.1
1/3	10-20	6.90	0.04	56.2	46.6	9.6	0.0	42.3	6.1
		Mednikarovo, non humus reclamation							
1/1	0-10	7.20	0.04	29.8	22.7	7.1	0.0	17.5	5.6
1/1	10-20	7.20	0.04	29.7	22.6	7.1	0.0	17.5	5.5
2/2	0-10	7.20	0.04	29.7	22.6	7.1	0.0	17.7	5.8
2/2	10-20	7.10	0.04	29.8	22.6	7.2	0.0	17.6	6.0
1/3	0-10	7.10	0.035	29.4	22.3	7.1	0.0	17.6	5.5
1/3	10-20	7.10	0.035	29.8	22.7	7.1	0.0	17.6	5.6
		Obruchishte, pine vegetation							
1/1	0-5	4.80	0.35	37.1	28.8	8.3	1.6	23.0	4.2
1/1	10-20	5.00	0.73	43.2	35.0	8.2	0.6	32.0	4.0
2/2	0-5	4.30	0.08	44.8	32.0	12.8	2.0	25.0	4.8
2/2	10-20	3.90	0.69	48.6	31.6	17.0	2.3	24.4	4.5
1/3	0-5	4.80	0.15	41.9	29.9	12.0	1.5	22.8	5.6
1/3	10-20	4.50	0.47	42.0	30.2	11.8	2.0	23.0	5.5
		Obruchishte, non vegetated							
1/1	0-10	3.30	1.26	60.8	46.7	14.1	14.6	26.0	6.0
1/1	10-20	3.30	1.12	60.7	44.7	16.0	14.8	25.4	5.8
2/2	0-10	3.20	1.30	70.0	53.8	16.2	14.4	34.0	5.8
2/2	10-20	3.20	1.30	71.0	54.6	16.4	14.5	34.2	5.8
2/3	0-10	3.00	1.80	75.0	58.0	17.0	25.1	31.5	5.4
2/3	10-20	3.10	2.00	75.0	58.2	16.8	20.9	39.6	5.4

The greatest differences between the studied geological materials are in the %< 0.01 mm particle fraction, which significantly influences on the structure, water regime and the sorption of nutrients (Garbuchev et al., 1975).

The highest levels of the exchangeable Ca (42.0-42.5) and Mg are found in the areas of Mednikarovo with humus reclamation, the lowest (17.5-17.7) are for Mednikarovo with non-humus reclamation. Exchangeable Al was established in Obruchishte, non-vegetated with the highest values (up to 25.1 cmol.kg^{-1}, Table 1).

The authors (Hristov and Banov 1996, Banov and Marinkina 2002) have found that reclaimed soils were of heavy texture which determines unfavorable hydro-physical properties.

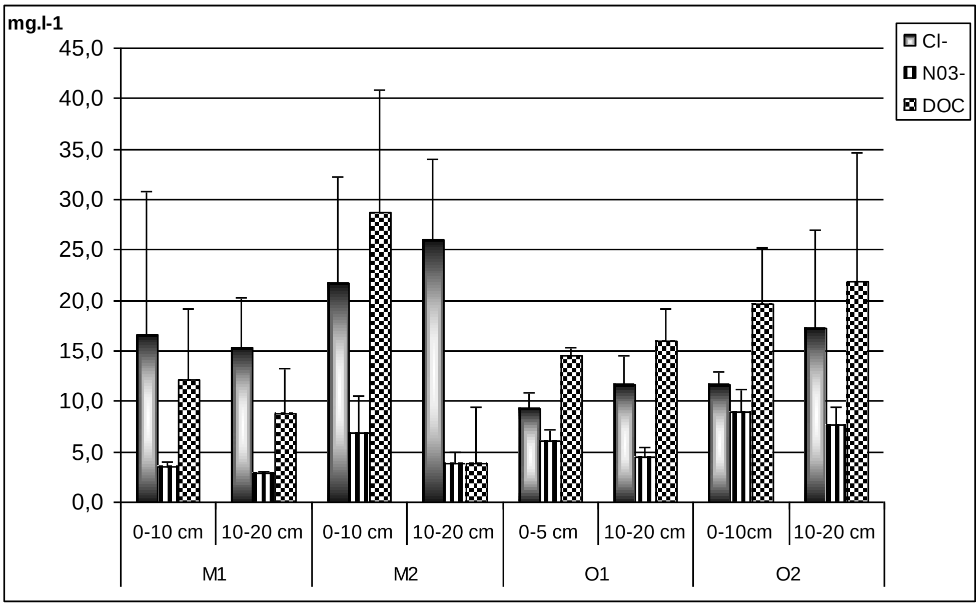

Figure 1. *Average content of Cl-, NO_3^- anions and DOC (mg.l^{-1}) in the studied plots: M1-Mednicarovo humus reclamation, M2-Mednicarovo non-humus reclamation, O1- Obruchishte pine-vegetated, O2- Obruchishte non-vegetated*

The chemical composition of the soil solution depends on soil type, geology, climatic conditions, as well as anthropogenic, technogenic and other impacts. The components of the solution (the cations and anions) are sensitive to these effects and respond in a different way. Significant differences in the concentration and distribution of the macroelements in soil solutions from natural and reclaimed soils were observed (Howell et al., 2017., Schaaf et al., 1999, Wilden et al., 1999). Apart from that, the composition and dynamics of the soil solution depends on the soil reclamation, the type and content of the coal materials, etc. Also low pH and high ion concentrations were observed, especially in the subsurface layers. The additional application of fly ash significantly changes the soil properties (Schaaf et al., 2005).

The content of the chloride anions (Figure 1) in the soil solutions has higher average values in Mednikarovo (non-humus reclamation) at both depths (21.7-26.0 mg.l^{-1}). At the other area at Obruchishte we observed nearly 2 times lower values (Obruchishte, pine vegetated, 9.3-11.7 mg.l^{-1}). Chlorine in the arable soils is the element with the most constant concentration in the soil solution. This could be explained with a transit status of chlorine in the agroecosystems. This element does not take significant part in the plant uptake and its chemical and physico-chemical fixation in soil is poor. According to (Chen et al., 2013) increased concentration of chloride in soil solution is observed in layers of reclaimed soils where fly ash content is higher because the solution equilibrium process is established slowlier. At all the sites the chloride concentrations do not exceed the maximum permissible levels limit for drinking waters (MPCL 250 mg.l^{-1}, Regulation No 9/2001).

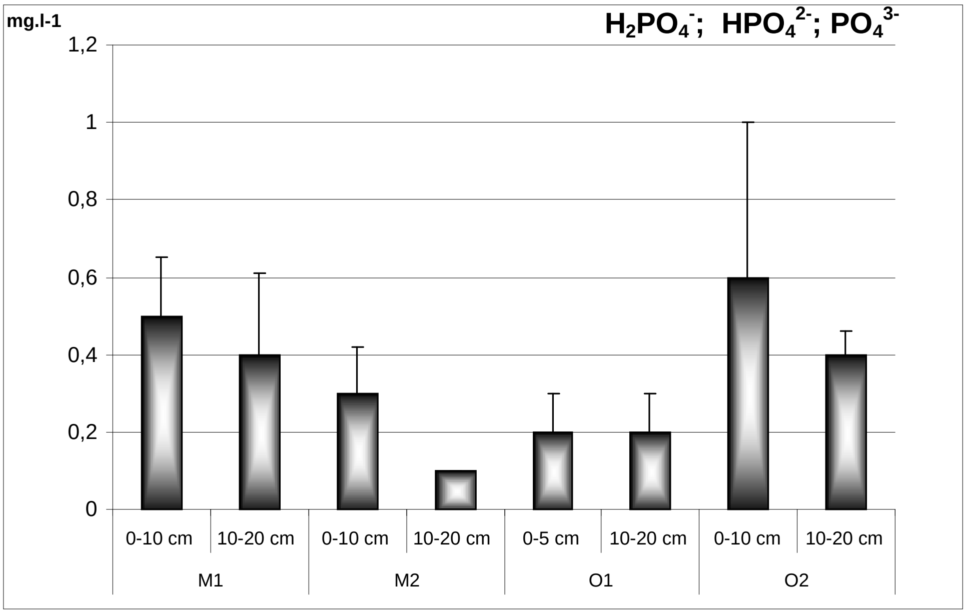

Figure 2. *Average content of the sum of* $H_2PO_4^-$; HPO_4^{2-}; PO_4^{3-} *(mg.l^{-1}) in the studied plots: M1-Mednicarovo humus reclamation, M2-Mednicarovo non-humus reclamation, O1- Obruchishte pine-vegetated, O2- Obruchishte non-vegetated*

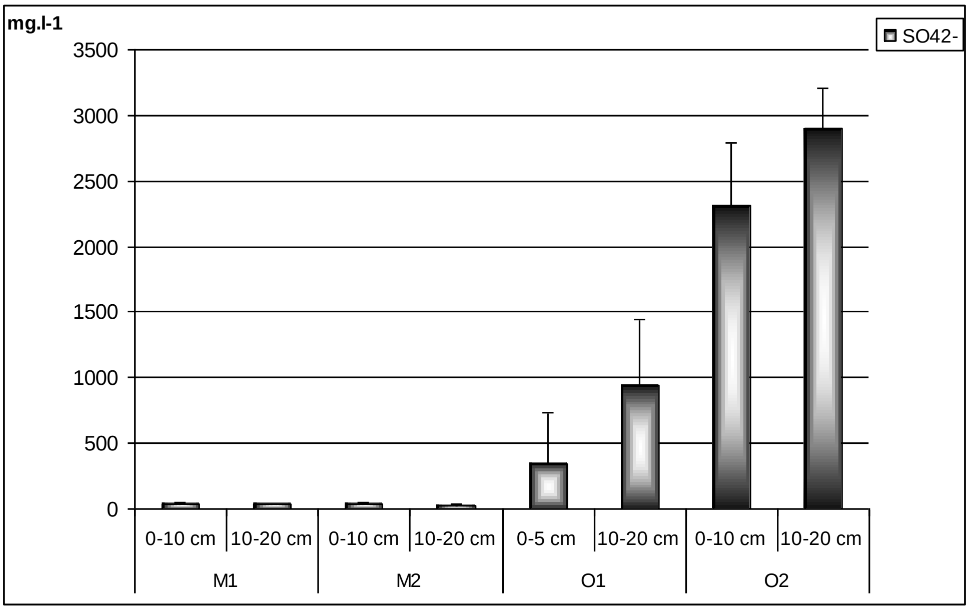

Figure 3. *Average content of* SO_4^{2-} *(mg.l^{-1}) in the studied plots: M1-Mednicarovo humus reclamation, M2-Mednicarovo non-humus reclamation, O1- Obruchishte pine-vegetated, O2- Obruchishte non-vegetated*

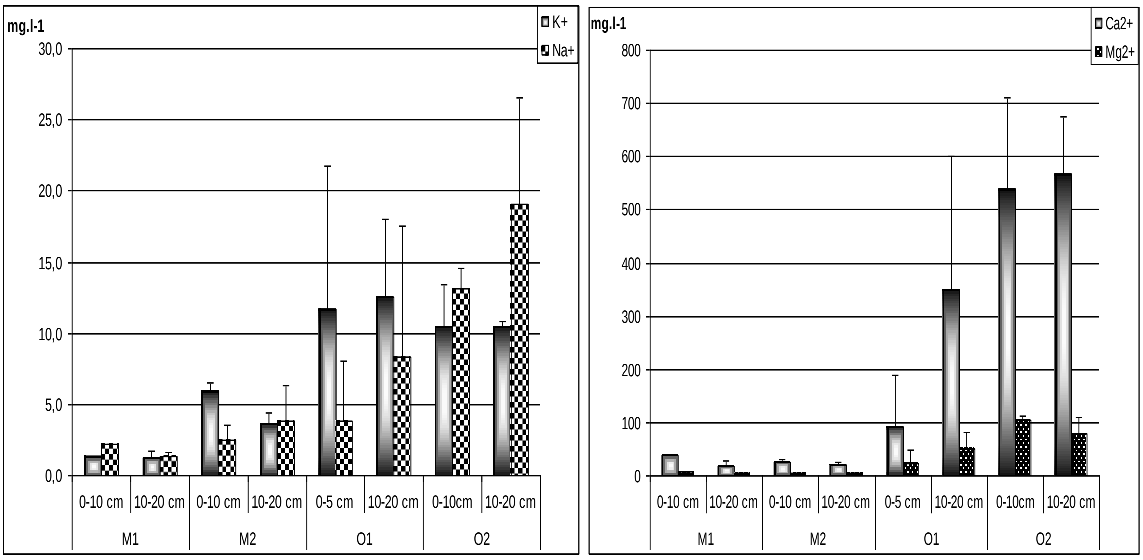

Figure 4. *Average content of K^+, Na^+, Ca^{2+} and Mg^{2+} (mg.l^{-1}) in the studied plots: M1-Mednicarovo humus reclamation, M2-Mednicarovo non-humus reclamation, O1- Obruchishte pine-vegetated, O2- Obruchishte non-vegetated*

It is found that a significant limiting factor in the reclaimed soils for growth of plants is the deficit of available nitrogen and phosphorus (Davies 1995). It was found that the average values of nitrate anions in all studied areas are low (from 2.8 to 8.9 mg.l^{-1}). A slightly higher nitrate concentration was recorded at Oruchishte, (non-vegetated site, 0-10 cm depth) but did not exceed the maximum permissible concentration limit for nitrate in drinking waters of MPCL 50 mg.l^{-1} (Regulation No 9/2001). Results show that in arable soils, nitrates and hydrocarbonates are usually the predominant anions balancing the ionic changes in solution caused by various sources (Stoicheva et al., 2003).

As regards the average content of DOC in the soil solutions (Figure1) from Mednikarovo (humus reclamation) and Obruchishte (pine-vegetated site), values are of low variation (in the range of 8.7 to 12.2 mg.l^{-1} and 14.4-15.9 mg.l^{-1} as compared to Mednikarovo (non-humus reclamation). At this site and at Obruchishte (non – vegetated site) the DOC content has the highest values (28.7 mg.l^{-1} and 21.9 mg.l^{-1}) .

Average concentrations of phosphates in solution at all sites ranged from 0.1 to 0.6 mg.l^{-1} (Figure 2). Higher values are established at Mednikarovo (humus reclamation) at both depths, and at Obruchishte (non-vegetated), which are near the limit or slightly exceeded the maximum concentration level of phosphates in drinking water (0.5 mg.l^{-1}). At the other sites the average content of phosphates is lower and varies less (Table 1).

Significant differences are found in the sulphates content in soil solutions for all sites (Figure 3). The average values are from 29.3 to 42.7 mg.l^{-1} at Mednikarovo and are in the range from 345.3 to 943.7 mg.l^{-1} at Obruchishte under pine forest. The highest concentrations (2313 - 2897 mg.l^{-1}) were observed at the non-vegetated site of Obruchishte as in depth of the profile sulphates were increased at all sites. Exceeded were the MPCL for sulphates of 250 mg.l^{-1} for drinking waters over 5 to 10 times.

The high sulphate salinity was caused by the high amount of sulphates in overburden materials associated with high contents of calcium and magnesium ions (Zheleva et al., 2004). The studies of (Garbuchev et al., 1975) have shown that yellow and green clays could be a suitable substrates for development of vegetation, however the high acidity of the black “greasy”clays may cause serious environmental consequences.

Some authors (Schaaf et al., 1999) have reported that mine soils containing a considerable amount of lignite and pyrite materials under pine vegetation had very low pH values and high concentrations of Fe^{n+} and SO_4^{2-}. These extremely acidic conditions are the precondition for the weathering of aluminum silicates and movement of acid products in depth of the profile. It often takes hundreds of years to improve soil structure and fertility. Our data correspond with those of Howell et al. (2017) who also found that nutrients in the profiles of reclaimed soils are very different from those in the natural soils and the levels of available phosphorus and potassium are significantly lower, while of S, Ca and Mg are much higher than those in natural soils.

Regarding the average K^+ and Na^+ concentrations in the solutions, the highest concentrations for sodium were recorded at the non-vegetated Obruchishte site (up to 19.1 $mg.l^{-1}$), and for potassium at Obruchishte under pine forest 12.53 $mg.l^{-1}$ for the 10-20 cm layer (Figure 4). As could be seen from the data in figure 4, in the solutions from the area of Obruchishte the highest contents of calcium and magnesium were found. A source of calcium can be the fly ash added as an amendment to the acidic Obruchishte spoils in 1970s with alkaline pH (Zheleva et al., 2004). At this site the variation in the average calcium content was very high reaching 567 $mg.l^{-1}$ which exceeds about four times the maximum permissible concentration limits MPCL 150 $mg.l^{-1}$ for drinking waters. In natural soil solutions calcium cations predominate, as well, and serve as ions-compensators of the negative charge of anions and dissociated acids in the soil solution.

Conclusion

The results from this study show that the measured soil solution parameters from the studied reclaimed sites from the area of Maritsa-Iztok coal mines show significant dynamics. A considerable variation in pH values was found at all tested sites, varying from neutral to extremely low pH at the area of Obruchishte. It was established that the content of the studied elements in the soil solutions does not exceed the MPCL for drinking water at Mednikarovo. Very high ionic concentrations were established at Obruchishte, (non-vegetated), especially sulphates, phosphates, calcium and magnesium ions, which significantly exceeded the maximum concentration limits for drinking water. The geological materials represented by yellow-green and gray-green clays used as a substrate for reclamation of the investigated sites do not considerably increase the ionic strength of the soil solution, but the presence of black “greasy” clays and fly ash which are mixed with the these substrates may cause a significant increase in ionic concentrations of major ions, thus posing a threat to contamination of the liquid phase of reclaimed soil.

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Contribution of Agricultural Wastes on Soil Aggregation, Soil Properties and Yield of Maize on Acidic Soil

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Abstract

The stability of soil aggregates against the impact of rainfall has become vital especially in South-eastern Nigeria whose soils are too fragile due to high rainfall distribution in the zone that facilities soil erosion. In trying to finding out ways of improving the aggregate stability of soils, two agricultural wastes (poultry droppings (PD) and saw dust ash (SDA) were applied individually and in combination of both at varying rates to evaluate its effects on soil aggregate stability, soil physicochemical properties and yield of maize. A randomized complete block design was used and the treatments were replicated three times. Pre and post planting soil samples were collected and analysed for physical and chemical soil properties using standard methods. Data collected from soil analyses and growth performances of maize were subjected to analysis of variance and significant treatment means were separated using least significant difference at 0.05 probability level. Results showed that plots amended with 10 t/ha PD + 10 t/ha SDA increased soil organic carbon by 25.4 %, soil total nitrogen by 25.7 %, effective cation exchange capacity by 34.3 % and base saturation by 19.2 %. Plots amended with 10 t/ha PD + 10 t/ha SDA reduced clay ratio (CR), clay dispersion index (CDI) and dispersion ratio (DR) by 75.2 %, 84.9 % and 93.7 % respectively while clay flocculation index (CFI) was increased by 82.3 %. The highest maize yield (74 kg/ha) was recorded from plots amended with 10 t/ha PD + 10 t/ha SDA. Therefore 10 t/ha PD + 10 t/ha SDA was recommended for improvement of soil properties, soil aggregate stability and yield of maize in acid soil.

Key words: Clay flocculation index, Dispersion ratio, Erosion, Soil erodibility, Dispersion index

Introduction

Soil degradation has been an environmental challenge affecting food production in Southern part of Nigeria. Soils of this region have high erodibility and therefore structurally unstable (Idowu and Oluwatosin, 2008; Nwachukwu and Onwuka, 2011). These soils are naturally prone to erosion due to their fragile nature as a result of the parent materials that formed the soils (Oguike and Mbagwu, 2009). Anthropogenic activities like bush burning, continuous cultivation and mining on hill side slopes contribute to high soil degradation in the region (Nwachukwu and Onwuka, 2011). Most arable farm lands have lost their agricultural potential with negative consequences to food security. These activities have reduced the organic matter content of soil thereby making the soil prone to erosion as a result of poor aggregate stability (Nwachukwu and Onwuka, 2011).

One of the methods of measuring the structural status of agricultural soils is by measuring the stability of their aggregates when in contact with water (Mbagwu et al., 1994). Use of organic amendment to increase the aggregate stability of soils susceptible to erosion has been examined in recent studies (Shainberg and Levy, 1994). One of such practice is the incorporation of organic and inorganic amendment on soil (Nutullah et al., 2015). Nutullah et al. (2015) reported significant relationships between total soil carbon and soil aggregation, bulk density, water retention and hydraulic conductivity on soils amended with organic residues. These relationships indicate that amending coarse-textured soils with organic amendments increases organic carbon content and improved saturated hydraulic conductivity, water stable aggregation and water retention (Nutullah et al., 2015). However, little literature is available on the effect of agricultural wastes on soil aggregate stability and how soil aggregation affects the yield of maize in the region. The aim of this work therefore was to evaluate the effect of two agricultural wastes on soil aggregate stability, soil physicochemical properties and yield of maize in an acid soil of Owerri, South-eastern Nigeria.

Materials and Methods

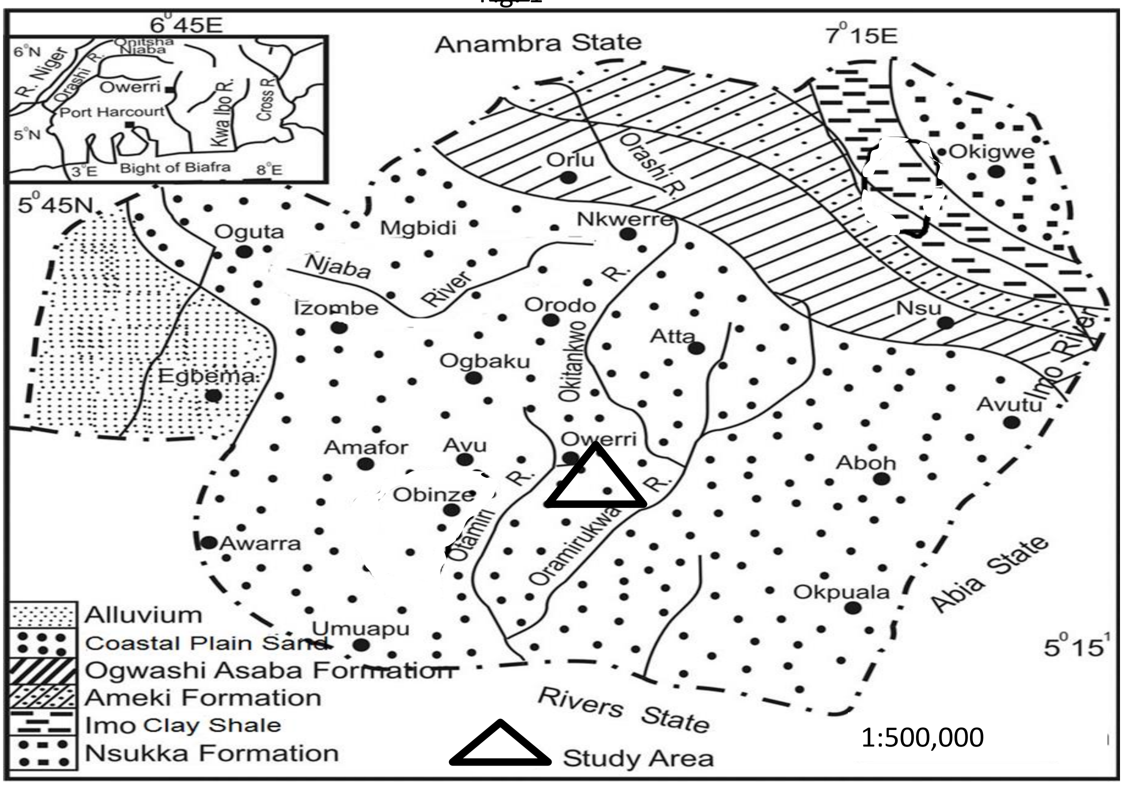
The Study Area

The study was conducted at the Teaching and Research Farm of Federal University of Technology Owerri, Imo State, South-eastern Nigeria during 2016 planting season. The area lies between Latitude 5° 21' N and 5° 28' N and Longitude 7' 02°E and 7° 16' E with an average annual rainfall range of 1950 mm – 2250 mm and annual temperature range of 27°C – 32°C. It has average relative humidity of 80%. The geologic material of soil in the region is an ultisol and classified as Typic Haplustult (FDALR, 1985), derived from coastal plain sands (Benin formation) of the Oligocene-Miocene geological era and are characterized by low organic matter, low cation exchange capacity and are highly leached (Onweremadu *et al.*, 2011). The region is a tropical rainforest with high anthropogenic activities, especially farming and deforestation and these deplete the vegetation Farming at subsistent level is a major socio economic activity of people in the area and soil fertility restoration is by bush fallow and application of inorganic fertilizers and inorganic manures.

Land Preparation

A two year fallow land, dominated by shrubs and grasses was used for the study. The area was manually cleared using cutlass and hoes and mapped out into 27 experimental plots. Composite soil samples were randomly collected at 0 – 30 cm depth using soil auger and soil core sampler was used to collect soil sample for bulk density determination. The samples were air dried at room temperature and sieved using 2 mm mesh sieve and then subjected to routine laboratory analysis using standard methods.

Fig 1



Geological Map of Imo State showing the Study Area.

Figure 1. *Geological map of Imo State showing the study location*

Field layout, treatments and experimental design

The experimental plots were mapped out into nine treatment plots using ranging pole and measuring tape. Each experimental plot measured 3 x 3 m with inter-plot distance of 1 m and inter-block distance of 2 m. The nine experimental plots were replicated three times given a total of 27 treatment plots. The beds were manually tilled with hoes and spades. Treatments applied consisted of control plot (T1), 5 t/ha PD (T2), 10 t/ha PD (T3), 5 t/ha SDA (T4), 5 t/ha SDA + 5 t/ha PD (T5), 5 t/ha PD + 10 t/ha SDA (T6), 10 t/ha SDA (T7), 5 t/ha SDA + 10 t/ha PD (T8), 10 t/ha SDA + 10 t/ha PD (T9). The treatments were applied on the experimental plots by broadcasting method and later incorporated into the soil using local hoe. The treatments were allowed to incubate for a week and thereafter maize seeds (Oba super II hybrid) were planted on the bed at a distance of 50 x 50 cm given a total of 27 plants per plot and a plant population of 30, 000 plants per hectare. At 13 weeks after planting, the maize cobs were harvested; sun dried and weighed using weighing balance. Soil samples were collected from each experimental plot 12 weeks after planting. The samples were air dried and sieved using 2 mm mesh and subjected to routine analysis. Similarly, some samples of poultry manure and saw dust ash were analysed for nutrient composition before the study.

Laboratory Analysis

Physical properties of the soil

The particle size distribution of the soil (sand, silt and clay fractions) was determined by hydrometer method according to the procedure of Gee and Or (2002). A set of soil sample was dispersed with calgon (DC) while another set was dispersed with water (DW) before the particle size fractions were determined. Bulk density (BD) was determined by core methods according to Grossman and Reinsch (2002). Total porosity of the soil was calculated from the result of bulk density using the formula:

Total porosity (TP) = $1 - \frac{\text{BD}}{\text{pd}} \quad \text{x } 100$ ....equation 1

where pd = particle density (2.65 g/cm^3) and BD = bulk density

Gravimetric moisture content (GMC) was determined using the formula

GMC = $\frac{\text{Wtmc}}{\text{Wtss}} \quad \text{x } 100$ ....equation 2

where Wtmc = weight of the moisture contained in soil sample; Wtss = weight of soil sample

Estimation of soil aggregate stability

Soil aggregate stability was estimated using four indices namely Clay Flocculation Index (CFI), Dispersion Ratio (DR), Clay Dispersion (CD) and Clay Ratio (CR) according to Igwe *et al.*, (1995) and Igwe and Obalum (2013).

DR = $\frac{(\%\text{ silt} + \%\text{ clay})\text{ (DW)}}{(\%\text{ silt} + \%\text{ clay})\text{ (DC)}}$ .... equation 3

CFI = $\frac{(\%\text{ clay (DC)} - \%\text{ clay (DW)}}{\%\text{ clay (DC)}}$ .... equation 4

CDI = $\frac{(\%\text{ clay (DW)}}{\%\text{ clay (DC)}} \text{x}100$ .... equation 5

CR = $\frac{(\%\text{ sand})}{(\%\text{clay} + \%\text{silt})}$ .... equation 6

where DC = dispersed in sodium hexametaphosphate (calgon), DW = dispersed in water

Low values of CR, DR and CDI indicate less erodibility and hence higher stability of soil micro aggregation. CFR is the reverse of the other three indices meaning that the higher the values of CFI the lower the stability of soil aggregate (Igwe and Obalum, 2013).

Soil chemical properties

Soil pH was determined in both water and in KCl using pH metre in soil / liquid suspension of 1: 2.5 according to Hendershot *et al.*, (1993). Organic carbon was determined using chromic acid wet oxidation method according to Nelson and Somers (1982). Total nitrogen was determined by Kjeldahl digestion method using concentrated H_2S0_4 and sodium copper sulphate catalyst mixture according to Bremner and Yeomans (1988). Available phosphorus was determined using Bray II solution according to Olsen and Somers (1982). Exchangeable Mg and Ca were extracted using ethylene diamine tetra acetic acid (EDTA) (Thomas, 1982) while exchangeable K and Na were extracted using 1 N neutral ammonium acetate (NH_4OAC) and then determined using flame photometer (Thomas, 1982). Exchangeable Acidity was measured titrimetrically using 1 N KCl against 0.05N Sodium hydroxide (Mclean, 1982) while effective cation exchange capacity was calculated from the summation of all exchangeable bases and total exchangeable acidity. Percentage Base

Saturation (PBS) was calculated by the summation of the total exchangeable bases divided by effective cation exchange capacity and then multiplied by 100.

Soil properties before treatment application and selected nutrient composition of agro-wastes used in the study.

The physico-chemical properties of soil used in the study are presented in Table 1. The soil was texturally loamy sand with high sand fraction and silt clay ratio showing advanced stages of weathering. The gravimetric moisture content was low and the soil was strongly acidic, low in organic carbon and exchangeable bases.

Selected nutrient content of the agricultural wastes used in the study are presented in Table 2. The wastes are rich in plant nutrient elements. Poultry droppings contained high values of nitrogen, phosphorus, organic carbon and magnesium than saw dust ash. Saw dust ash contained high value of potassium with high pH.

Table 1. *Physicochemical properties of the soil before the study*

Soil property	Unit	Value
Sand	g/kg	921
Silt	g/kg	15
Clay	g/kg	64
Textural class		Loamy sand
Silt/clay		0.23
Bulk density	g/cm^3	1.35
Total porosity	%	49.1
Gravimetric moisture content	g/kg	117.2
pH (H_2O)		5.11
Organic carbon	g/kg	6.36
Total nitrogen	g/kg	0.56
Available phosphorus	mg/kg	14.3
Exchangeable Ca	cmol/kg	1.40
Exchangeable Mg	cmol/kg	1.01
Exchangeable K	cmol/kg	0.12
Exchangeable Na	cmol/kg	0.04
Exchangeable H	cmol/kg	0.32
Exchangeable Al	cmol/kg	0.59
Effective cation exchange capacity (ECEC)	cmol/kg	3.48
Base saturation	%	73.8

Table 2. *Selected chemical properties of the amendments used in the study*

Chemical property	Unit	Saw dust ash (SDA)	Poultry manure (PD)
pH (H_2O)		9.55	6.83
Nitrogen	g/kg	0.22	4.32
Phosphorus	mg/kg	1.42	7.0
Potassium	g/kg	4.30	3.21
Organic carbon	g/kg	7.31	13.5
C/N		33.2	3.13
Calcium	g/kg	5.90	6.50
Magnesium	g/kg	3.12	5.21

Statistical analysis

Results from laboratory analysis and yield of maize were subjected to Analysis of Variance (ANOVA) while significant means among treatments were separated using Least Significant Difference (LSD) at 5% probability level. Relationship between aggregate stability indices and soil properties was determined using correlation analysis.

Results and Discussion

Effect of the amendments on soil physical properties

The amendments did not significantly (p = 0.05) change the textural class of the soil (Table 3). Soil bulk density was significantly (p = 0.05) reduced in the plots amended with the manure when compared to the control plots. Plots amended with 10 t/ha PD + 10 t/ha SDA recorded the lowest soil density (1.07 g/cm^3). Amended plots significant (p = 0.05) increase in soil total porosity as compared to un-amended plots. Plots amended with 10 t/ha PD + 10 t/ha SDA recorded the highest total porosity of 59.7%. Application of the agro-wastes significantly (p = 0.05) increased soil gravimetric moisture content when compared to un-amended plots. The highest gravimetric moisture content of 369.2 g/kg was recorded in plots treated with 10 t/ha PD + 10 t/ha SDA.

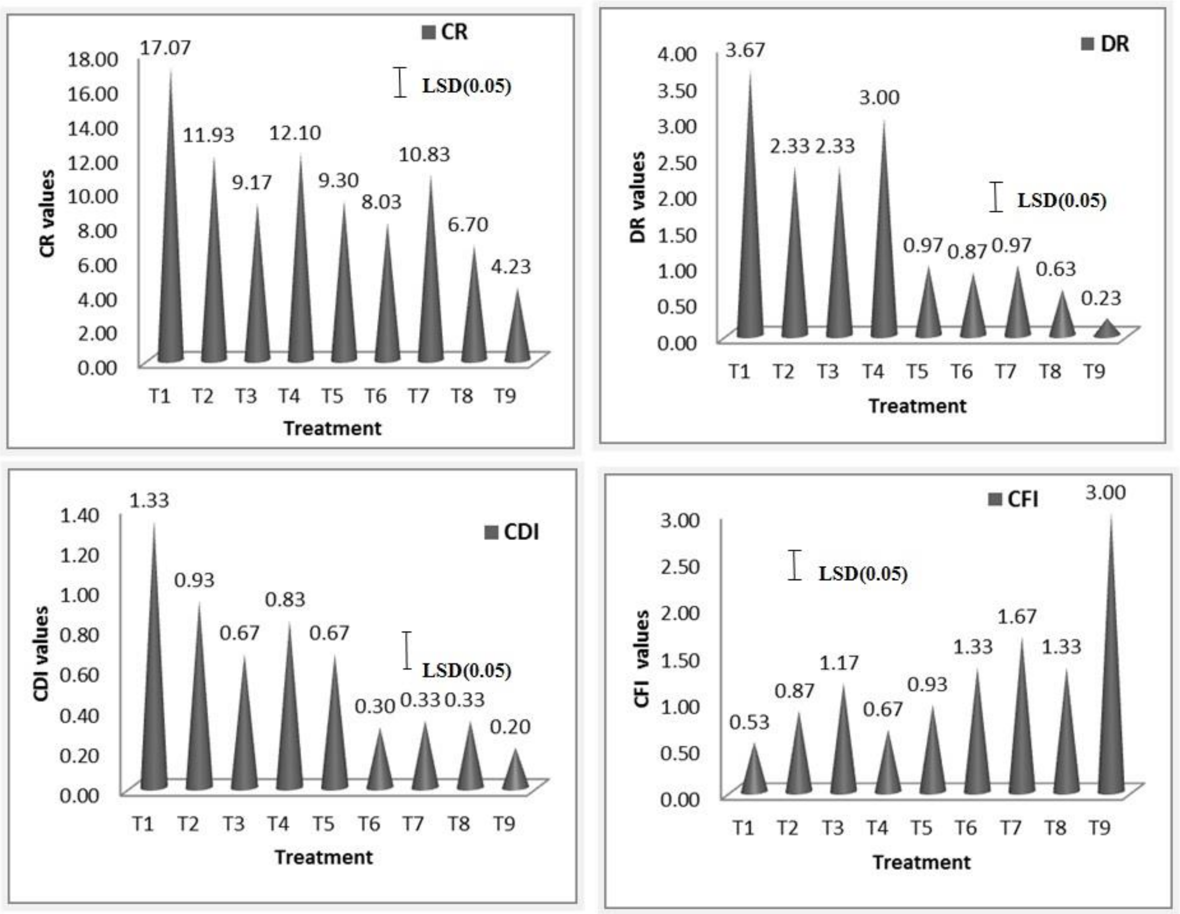
Table 3. *Effect of the amendments on soil physical properties*

Treatment	Sand g/kg	Silt g/kg	Clay g/kg	Textural class	Silt/Clay	BD g/cm^3	TP %	GMC g/kg
Control	922.9	16.2	60.9	Loamy sand	0.19	1.37	48.40	116.8
5 t/ha PM	940.4	19.2	40.4	Loamy sand	1.17	1.30	51.01	144.9
10 t/ha PM	928.9	19.8	49.8	Loamy sand	0.69	1.20	55.36	224.1
5 t/ha SDA	913.9	39.5	44.2	Loamy sand	1.10	1.19	56.63	123.1
5 t/ha PM + 5 t/ha SDA	895.6	22.8	81.2	Loamy sand	0.16	1.27	52.20	243.9
5 t/ha PM + 10 t/ha SDA	902.9	47.8	48.9	Loamy sand	1.0	1.24	55.0	241.3
10 t/ha SDA	895.9	46.1	55.9	Loamy sand	0.48	1.29	52.87	168.2
10 t/ha PM + 5 t/ha SDA	949.2	26.1	26.6	Loamy sand	0.36	1.26	54.1	311.0
10 t/ha PM + 10 t/ha SDA	929.6	29.5	40.9	Loamy sand	1.04	1.07	59.69	369.2
LSD(0.05)	NS	NS	NS		NS	0.076	5.278	27.71

NS = not significant, BD = Bulk density, TP = Total porosity, GMC = Gravimetric moisture content

Effect of the amendments on soil aggregate stability indices.

Aggregate stability was evaluated using four indices namely Clay Ratio (CR), Dispersion Ratio (DR) Clay Dispersion Index (CDI) and Clay Flocculation Ratio (CFR) as shown in Figure 2. Low values of CR, DR and CDI indicate less erodibility and hence higher stability of soil micro aggregation. CFR is the reverse of the other three indices meaning that the higher the values of CFI the lower the erodibility of the soil (Igwe and Obalum, 2013). Results in Figure 2 showed that plots amended with agro-wastes significantly (p = 0.05) increased the stability of soil aggregates when compared to un-amended plots. Plots treated with 10 t/ha SDA + 10 t/ha PD recorded 4.23 for CR, 0.23 for DR, 0.20 for CDI and 3.0 for CFR. Also, increase in the rate of the amendments resulted to higher micro aggregation of the soil.



CR = Clay ratio, DR = Dispersion ratio, CDI = Clay dispersion index, CFI = Clay flocculation index. The lower the values of CR, DR AND CDI, the more the stability of the soil to resist erosion while the higher the values of CFI, the higher the stability of the soil. T1 = control, T2 = 5 t/ha PM, T3 = 10 t/ha PM, T4 = 5 t/ha SDA, T5 = 5 t/ha PM +5 t/ha SDA, T6 = 5 t/ha PM + 10 t/ha SDA, T7 = 10 t/ha SDA, T8 = 10 t/ha PM + 5 t/ha SDA, T9 = 10 t/ha PM + 10 t/ha SDA

Figure 2. *Effect of poultry manure and saw dust ash on soil aggregate stability.*

Effect of the amendments on soil chemical properties

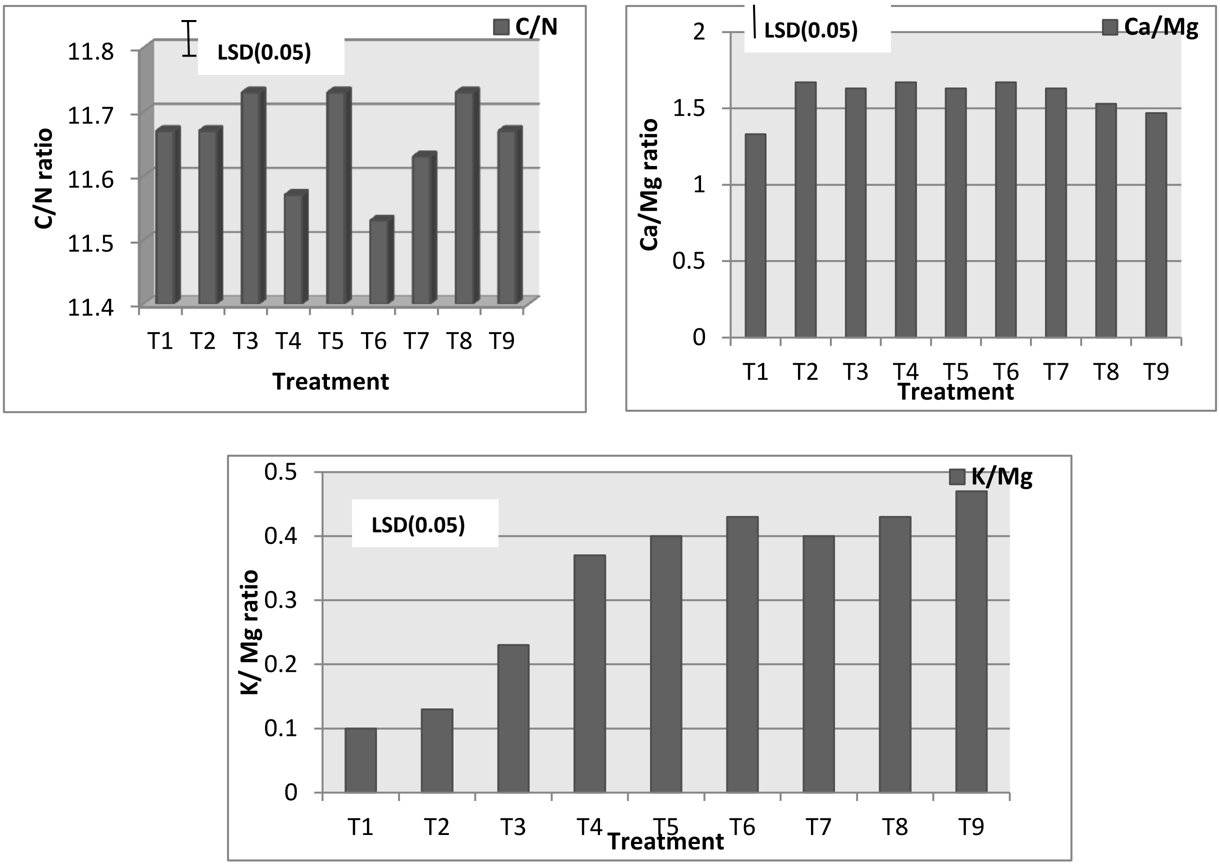
The treatments significantly (p = 0.05) increased soil pH when compared to control plots (Table 4). Plots amended with 10 t/ha PD + 10 t/ha SDA recorded the highest value of soil pH in water (5.29) and in KCl (4.75). The same rate recorded the highest values of soil organic carbon (8.67 g/kg), total nitrogen (0.74 g/kg) and available phosphorus (18.10 mg/kg) when compared to other treatments. Similar trend was observed in exchangeable bases, effective cation exchange capacity and base saturation. Plots amended with 10 t/ha PD + 10 t/ha SDA recorded the lowest total exchangeable acidity of 0.53 cmol/kg.

Results on the fertility ratios as affected by the amendments are shown in Figure 3. Results showed that application of the organic manure significantly (p = 0.05) influenced carbon to nitrogen ratio (C/N) and potassium to magnesium ratio (K/Mg) while no effect was observed in calcium to magnesium ratio (Ca/Mg). Plots amended with 10 t/ha SDA + 10 t/ha PD recorded the highest K/Mg ratio of 0.47 as compared to 0.1 in the control. There was irregular trend on C/N ratio in all the experimental plots.

Table 4. *Effect of the amendments on soil chemical properties*

Treatment	pH	pH	OC	TN	C/N	Avail. P	Exch						
	H_2O	KCl	g/kg	g/kg		Mg/kg	Ca	Mg	K	Na	TEA	ECEC	BS
							Cmol/kg						%
Control	5.01	4.14	6.47	0.55	11.67	15.23	1.50	1.09	0.13	0.03	0.99	3.74	73.30
5 t/ha PD	5.13	4.44	7.47	0.64	11.67	16.25	2.25	1.36	0.17	0.04	0.62	4.45	86.03
10 t/ha PD	5.13	4.53	7.61	0.65	11.73	16.37	2.33	1.39	0.37	0.03	0.66	4.79	86.30
5t/ha SDA	5.25	4.53	7.23	0.62	11.57	16.57	2.30	1.34	0.49	0.04	0.62	4.79	87.00
5t/ha PD + 5t/ha SDA	5.26	4.55	7.67	0.65	11.73	16.93	2.44	1.45	0.59	0.03	0.59	5.09	88.43
5t/ha PD + 10t/ha SDA	5.27	4.55	8.18	0.71	11.53	17.40	2.58	1.55	0.68	0.03	0.53	5.38	90.07
10t/ha SDA	5.26	4.57	7.41	0.63	11.63	16.87	2.43	1.49	0.64	0.04	0.49	5.08	90.40
10t/ha PD + 5t/ha SDA	5.27	4.70	8.41	0.72	11.73	17.40	2.54	1.66	0.72	0.06	0.51	5.49	90.60
10t/ha PD+10t/ha SDA	5.29	4.75	8.67	0.74	11.67	18.10	2.56	1.74	0.81	0.06	0.53	5.69	90.77
%CV	0.10	0.70	1.10	1.00	0.60	0.70	5.30	2.60	5.40	42.30	9.20	3.60	1.20
LSD(0.05)	**0.02**	**0.09**	**0.48**	**0.04**	**0.26**	**0.49**	**0.3**	**0.1**	**0.09**	**NS**	**0.15**	**0.42**	**2.83**

NS = Not significant at 0.05 probability, Exch = exchangeable, OC = organic carbon, TN = total N, C/N = carbon to nitrogen ratio, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, BS = base saturation, PD =poultry dropping, SDA = saw dust ash



T1 = control, T2 = 5 t/ha PM, T3 = 10 t/ha PM, T4 = 5 t/ha SDA, T5 = 5 t/ha PM +5 t/ha SDA, T6 = 5 t/ha PM + 10 t/ha SDA, T7 = 10 t/ha SDA, T8 = 10 t/ha PM + 5 t/ha SDA, T9 = 10 t/ha PM + 10 t/ha SDA

Figure 3. *Fertility ratios as influenced by the amendments*

Relationship between soil aggregate stability indices and soil chemical properties

Relationship between soil aggregate stability indices and soil chemical properties are presented in Table 5. Significant negative correlation existed between CDI and base saturation (r = -0.901), exchangeable Ca (r = -0.988), ECEC (r =.-0.961), exchangeable K (r = -0.925) and with other soil chemical properties. Similar interactions were observed between CR and DR and soil properties such as organic carbon (Table 5).

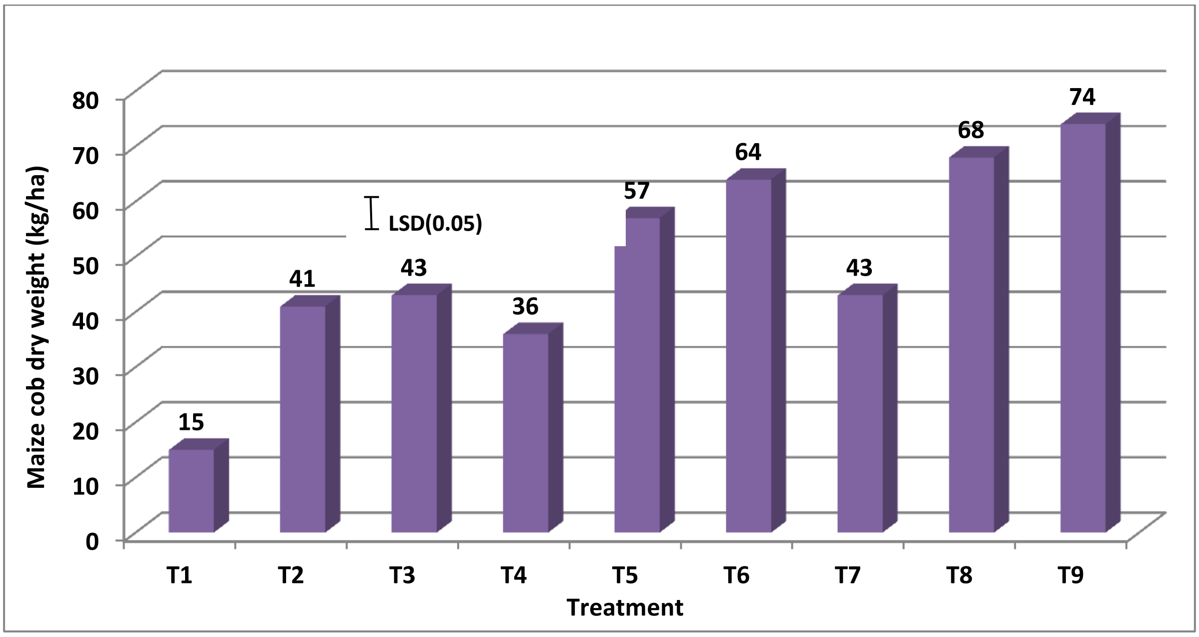
Table 5. *Relationship between soil erodibility indices and soil properties*

Soil property	**CDI**	**CR**	**DR**	**CFI**
Base saturation	-0.901**	-0.846**	-0.832**	0.570*
C/N ratio	0.114	-0.126	-0.085	0.032
Exchangeable Calcium	-0.899**	-0.883**	-0.837**	0.559*
Ca/Mg ratio	-0.313	-0.238	-0.197	-0.138
ECEC	-0.961**	-0.951**	-0.921**	0.727**
Exchangeable K	-0.925**	-0.842**	-0.883**	0.709**
k/Mg ratio	-0.873**	-0.778**	-0.821**	0.604**
Exchangeable Mg	-0.945**	-0.965**	-0.934**	0.806**
Organic Carbon	-0.878**	-0.979**	-0.878**	0.747**
Soil pH	-0.865**	-0.780**	-0.820**	0.555*
Total exchangeable acidity	0.888**	0.796**	0.823**	-0.544*
Total exchangeable bases	-0.964**	-0.938**	-0.919**	0.706**
Total Nitrogen	-0.874**	-0.967**	-0.860**	0.724**

*and ** = significant at 0.05 and 0.01 probability levels respectively, CR = clay ration, DR = dispersion ratio, CDI = clay dispersion index, CFI clay flocculation index

Effect of amendments on the yield of maize

Application of the amendments significantly (p = 0.05) increased the yield of maize as shown in Figure 4. Plots amended with 10 t/ha PD + 10 t/ha SDA recorded the highest maize yield (74 kg/ha) when compared to other treatments. Combined application of saw dust ash and poultry droppings increased the yield of maize more than when they are applied individually (Figure 4).



T1 = control, T2 = 5 t/ha PM, T3 = 10 t/ha PM, T4 = 5 t/ha SDA, T5 = 5 t/ha PM +5 t/ha SDA, T6 = 5 t/ha PM + 10 t/ha SDA, T7 = 10 t/ha SDA, T8 = 10 t/ha PM + 5 t/ha SDA, T9 = 10 t/ha PM + 10 t/ha SDA

Figure 4. *Effect of amendments on the yield of maize (zea mays)*

The properties of the soil used in the study showed that there is need to improve the fertility status of the soil for better crop performance since the essential nutrients were below the critical levels recommended by FAO (2006) while there was higher plant nutrient elements in the amendments used in the study. Therefore applying these wastes on the degraded soil of the study area is expected to improve soil aggregation and soil fertility status.

The amendments did not change the textural class of the amended soil. This observation was in agreement with Troech and Thompson (1993) and Adikwu *et al*., (2012) who stated that good soil management practices may slightly raise the values of soil particle sizes and improve soil productivity but cannot change the textural class. According to Fit-Patrick (1986), textural class of the soil is a function of weathering in association with parent materials influenced by climate over time. Reduction of soil bulk density in the amended soil agreed with the findings of Tekwa *et al*., (2010) that worked on rice mill husk and found out that application of rice mill husk reduced soil bulk density as compared to un-amended plots. Improvement of soil properties such as soil aeration and moisture content might increase soil biodiversity and soil organic matter that could reduce soil bulk density. Similarly, Li *et al.,* (2011) noted that application of organic wastes increased soil macro and meso-pore volume due to an increase in organic matter content, better aggregation and water transmission rate. Increase in soil gravimetric moisture content could be due to an increase in total porosity, reduction in soil bulk density and better soil aggregation. This finding was in concord with Mbah and Nneji (2010) that water holding capacity depends on soil total porosity and size distribution of its pores.

Plots amended with the organic wastes reduced the vulnerability of soil to erosion as seen in the low values of DR, CDI and CR and increase in the rate of the manure reduced the value of these soil aggregate stability indices. This result was in concord with the findings of Nutullah *et al*., (2015) who noted that increasing dose application of organic wastes in an acidic soil increases soil aggregate stability. Similar results were reported by Li and Zhang (2007) and Hati *et al.,* (2008) when they amended soil with farm yard manure. Improvement of the stability of the soil with application of these wastes could be due to increased organic matter since soil organic matter is a key factor in the formation of soil stable aggregate. Nutullah *et al.,* (2015) recorded significant positive relationship between soil aggregate stability index and soil organic carbon content. Uwanuruocha and Nwachukwu (2012) stated that organic constituents of the soil are very important because of their influence on stability of soil aggregates.

Increase in the organic carbon content in plots amended with the organic wastes could be attributed to increase in moisture retention, improved soil micro-aggregation and reduction in bulk density which created a favourable environment for microbial activity, decomposition and mineralization of organic matter. These conditions result to an increase in soil pH and basic cations. These findings are in agreement with Akanbi *et al.,* (2002), Ewulo *et al.,* (2009) and Ayeni, (2008), who observed that application of organic wastes improved soil organic matter and increased moisture retention. Increase in exchangeable cation could be attributed to an increase in soil pH due to manure application and an increase in organic matter that acts as a sink for exchangeable cations (Onwudike, 2010). Irregular trend on C/N ratio in all the experimental plots indicated different degrees of mineralization of the applied amendments.

Significant positive relationships existed between CFI and soil properties except with total exchangeable acidity. Increase in the organic carbon due to application of these manures as well as higher values of ECEC and exchangeable bases reduced the value of CR, CDI and DR and also increased the value of CFI. This is because soil organic matter plays a vital role in the formation of soil aggregation. Therefore factors that affect soil organic matter will directly or indirectly influence soil aggregate stability. Favourable soil pH which enhances availability of exchangeable cations, microbial population and reduction in soil compaction will improve soil micro aggregation. These findings are in concord with previous works of Nutullah *et al.*, (2015) and Rosool *et al.*, (2008) who recorded significant relationship between soil aggregate stability index and soil organic matter. Uwanuruochi and Nwachukwu (2012) stated that organic constituents of the soil are very important due to their influence on the stability of soil aggregate while Haynes and Naidu (1998) found out that increase in soil organic matter content as a result of organic manure application improves pore structure of the soil.

Increase in the cob yield with application of these agro –wastes could be attributed to the nutrient elements supplied by these amendments (Table 2) as well as the improvement in the soil physical condition such as reduced bulk density, increase in total porosity and water retention as well as increase in soil organic matter. Increase in the aggregate stability of the soil as shown in the values of DR, CR and CDI could contribute to an increase in the yield of maize. These attributes play significant role in increasing soil aeration and soil biodiversity (Jayaprakash et al., 2003) with an attendant high crop yield. These findings are in concord with previous works by Kumar and Puri (2001), Verma et al (2003) and Ajaz et al (2013) who reported that there is a positive effect of organic manure on yield contributing characters of maize.

Conclusion

This study showed that combined application of agricultural wastes like poultry droppings and saw dust ash are effective in improving soil organic carbon, soil total nitrogen and other physicochemical properties of fragile soils. Combined application of 10 t/ha SDA + 10 t/ha PM proved more effective in increasing these soil properties than other treatments evaluated in this work as well as increasing the yield of maize. Since formation of stable soil aggregates is an important soil quality for agricultural sustainability, application of 10 t/ha SDA + 10 t/ha PM is recommended for soil aggregate stability, soil fertility improvement and yield of maize in soils of similar condition.

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Development of Scheduling Irrigation in Bulgaria

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Abstract

The paper traces the emergence and development of the problem of scheduling irrigation as a scientific and practical issue at the Institute of Soil Science "N. Poushkarov" for half a century. The main participants in this process and the leading scientific publications are noted.

Key words: scheduling irrigation, computer software, evapotranspiration, FAO project.

Introduction

The reason for writing this paper is the fact that some Bulgarian researchers due to lack of knowledge or deliberately do not cite the initiators of the scientific and practical achievements in the scheduling irrigation problem in Bulgaria. Here are the facts about this problem.

Beginning

My involvement with the problem was caused by Dr. Howard Haise during his visit in May 1972 and October 1973, as a consultant on soil physics and irrigation to the FAO project AGl:DP/BUL/69/506 at the N. Poushkarov Institute of Soil Science (H. Haise, 1973; H. Haise, 1973a). Before leaving, he left written recommendations for work on these issues at the Institute, both scientifically and practically. One of his main recommendations was to start research, development and implementation of a system for programming irrigation recommendations. He provided literature on the issue (H. Penman, 1948; M. Jensen, H. Haise, 1963; M. Jensen, D. Heermann, 1970; R. Follett et al, 1973; D. Kincaid, D. Heermann, 1974) and give recommendations to test Dr. Jensen's Kansas Programming System in an experimental field using the Wang 700B Programmable Calculator.

Such a system was developed in the United States in 1969 and has since been successfully exploited in the states of Arizona, Idaho and Nebraska in drought and semi-dry areas for different crops. Between 1969 and 1971, the Nebraska system used a large electronic computing machine the CDC-6400, located in Colorado University, Fort Collins. Data from daily meteorological observations and irrigation data at the Mitchell experimental station were telephoned twice a week to the computing center, where they were returned by post to the station after processing. Irrigation recommendations arrived in two days, indicating the need to perform the calculations at the station itself.

In the year 1972, small programmable calculators Wang 600 and Wang 700 were delivered to the station. Irrigation programs were processed for these small machines. By using the calculators, it has become possible to daily adjust the irrigation data and recommendations to be available to irrigation specialists immediately without the need for data transmission at a distance.

In essence, this system uses readily available data on climate, soil and crops to predict when to irrigate and how much water to consume. The calculations have two stages - the first is for the determination of water consumption and the second one is by balance to find the necessary quantities of water for irrigation.

Since the Poushkarov Institute has a small Wang 700 calculator, Dr Haise left the computational programs and their description for use. The materials are stored with me. Not once have I asked different specialists if they will be interested in them, but so far they have not been used by anyone.

On 29.X.1973, by the initiative of Dr. Devan (then the FAO project leader), a meeting was held with the participation of Dr. A. Behar, Dr. Dinchev from Soil Irrigation System department, Dr. L. Glogov, Prof. Krafti, Dr. Varlev, at the end of which I was also presented. The issue of experimenting the system according Dr. H. Haise's recommendations was discussed. In conclusion, it was recommended to set up a working group for testing the method in one experimental station in parallel with a production experiment in the Agroindustrial Complex (AIC). However, after leaving Dr. Devan at the beginning of 1974, no one took the initiative and the working group was not set up.

According to colleagues from the Department of Soil Physics, in 1974, there was another meeting at the Poushkarov Institute with representatives from the Institute of Hydrotechnics and Meliorations, for which I have not been told. I do not know if there is something about development of this problem in the Institute of Hydrotechnics and Meliorations.

In a conversation with Professor G. Krafti I realized that he was interested in the scientific side of the matter - he developed his own method and wanted to use separate elements of the finished work but did not deal with the practical implementation of the system in AIC. Separate collaborators from the Institute have expressed the view that the ready implementation of Dr. Haise would have a significant agronomic and economic effect, but nobody has put it as a task. It stimulates me on 1.II.1975 to present to the Institute's Director a memorandum (A. Sadovski, 1975) to challenge actions by his side.

I made advise and recommended the following:

1. To set up a working team who, with the assistance of AIC specialists, will plan and conduct a production experiment in 1-2 experimental stations and 5-10 fields in the AIC to determine the efficiency and the accuracy of the proposed method.
2. In case of positive results, continue the research work of Dr. Hayes and simultaneously extend the production experiment of larger irrigated areas.
3. As the main flow of information arises from decentralized - climatic data from stations throughout the country, it will be correct that the processing by computers will also be decentralized - in the AIC or the territorial computing centers.
4. In the future work on the Automated soil and agrochemical servicing system for agriculture and current prediction of the yields, provision should be made and the connection with the

irrigation system as the irrigation programming algorithms shall be developed centrally at the Institute and then transmitted for use by centers on the country.

In conclusion, I believed that the question raised is of great importance for the country, as water resources are limited and available quantities have to be used optimally.

Development

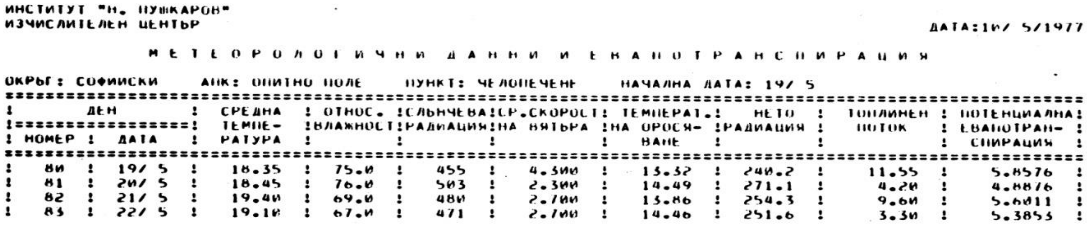
In May 1976 was held in Sofia an Experts Panel (FAO, 1976) on computerized soil management with participation of FAO consultants: Prof. Dr. M. Elgabaly, Dr. S. Bie, Dr. J. Gower, Mr. J. Riquier, Mr. N. Stalbrand, Mr. J. Rjks and several member of the N. Poushkarov Institute staff. As a conclusion several recommendations have been made. One of them was concerned with irrigation: Experiments are required to verity the irrigation recommendations and to include measurements on infiltration, permeability, moisture storage capacity and crop coefficients. When estimating water use for optimal yield, fertilizer recommendations cannot be ignored. Climatic data used for irrigation recommendations should be kept in the original (raw data) form. They can then be used to derive frequency estimates for irrigation and land productivity evaluation. The agrometeorological network should be strengthened. The Panel will supply further information on suitable stations equipment. Close cooperation with the National Hydrometeorological Service is urged.

It stimulates me to start work and in the period 1976 - 1978 to develop an analogous system of computer software with several modifications and additions in BASIC program language at the N. Poushkarov Institute Computing Center for NOVA-ECLIPSE minicomputer (Data General, 1975) with some help of Dr. I. Christov. After computer experiments and field experiments conducted in 1977 - 1978, it has become possible to apply this new system of forecasting and management of scheduling irrigation. The results are presented in a number of publications (A. Sadovski, 1976; G. Krafti et al. 1980; G. Krafti et al., 1980a; G. Krafti et. al., 1981; I. Christov, A. Sadovski, 1984). Computer outputs (Fig. 1 and Fig. 2) from the new irrigation forecasting and management system for experimental field in Chelopechene (1977) are provided as an illustration.

Table 1. *Measured (M1) and calculated (M2) water stock for the layer 0 - 80 cm.*

Date	M1 (mm)	M2 (mm)	Difference (%)
5.VI	262.0	272.1	3.9
13.VI	251.9	256.0	1.6
30.VI	264.0	263.4	-0.3
11.VII	223.0	217.2	-2.6
25.VII	231.6	236.9	2.2
8.VIII	241.2	246.4	2.2
25.VIII	271.4	278.5	2.6

With the help of the described complex computer model was performed operational management of the irrigation regime on maize located in the experimental field of the N. Poushkarov Institute near G. Lozen, Sofia District (G. Krafti et al., 1980), as well as through a production experiment with maize held in eight modular units located in different Bulgarian ecological regions, which confirmed the universality of the model. The meteorological indicators for the vegetation period were taken from the Botunets hydro-meteorological station situated near the fields, and the daily solar radiation data – from the National Institute of Meteorology and Hydrology in Sofia. Potential evapotranspiration was determined by compensatory type lysimeters. Water storage in soil was followed by soil samples with the TLC method. The detected initial water stock is used to determine water deficit. The comparison of the average experimental values of the water stock in the soil with the calculated values based on the computer model is presented in Table 1. As can be seen, the values obtained using the computer model show an impressive degree of coincidence with the measurements of soil samples.



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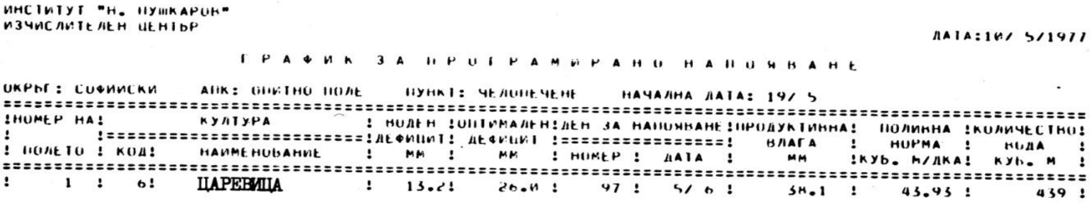
ИНСТИТУТ "Н. ПУШКАРОВ"
ИЗЧИСЛИТЕЛЕН ЦЕНТЬР                                                                              ДАТА:10/ 5/1977

                   М Е Т Е О Р О Л О Г И Ч Н И   Д А Н Н И   И   Е В А П О Т Р А Н С П И Р А Ц И Я

ОКРЬГ: СОФИИСКИ     АПК: ОПИТНО ПОЛЕ     ПУНКТ: ЧЕЛОПЕЧЕНЕ     НАЧАЛНА ДАТА: 19/ 5
===========================================================================================================
!        ДЕН        !  СРЕДНА  ! ОТНОС.  !СЛЬНЧЕВА!СР.СКОРОСТ! ТЕМПЕРАТ.!   НЕТО   !  ТОПЛИНЕН  ! ПОТЕНЦИАЛНА!
!===================!  ТЕМПЕ-  !ВЛАЖНОСТ!РАДИАЦИЯ!НА ВЯТЬРА !НА ОРОСЯ- !РАДИАЦИЯ !   ПОТОК    ! ЕВАПОТРАН- !
! НОМЕР !   ДАТА    !  РАТУРА  !        !        !          !   ВАНЕ   !          !            !  СПИРАЦИЯ  !
===========================================================================================================
!   80  !   19/ 5   !  18.35   !  75.0  !  455   !  4.500   !  13.32   !  240.2   !   11.55    !   5.8576   !
!   81  !   20/ 5   !  18.45   !  76.0  !  503   !  2.300   !  14.49   !  271.1   !    4.20    !   4.8876   !
!   82  !   21/ 5   !  19.40   !  69.0  !  480   !  2.700   !  13.86   !  254.3   !    9.60    !   5.6011   !
!   83  !   22/ 5   !  19.10   !  67.0  !  471   !  2.700   !  14.46   !  251.6   !    3.30    !   5.3853   !
```

Figure. 1. *Output from Penman program (original in Bulgarian)*



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ИНСТИТУТ "Н. ПУШКАРОВ"
ИЗЧИСЛИТЕЛЕН ЦЕНТЬР                                                                              ДАТА:10/ 5/1977

                        Г Р А Ф И К   З А   П Р О Г Р А М И Р А Н О   Н А П О Я В А Н Е

ОКРЬГ: СОФИИСКИ     АПК: ОПИТНО ПОЛЕ     ПУНКТ: ЧЕЛОПЕЧЕНЕ     НАЧАЛНА ДАТА: 19/ 5
===========================================================================================================
!НОМЕР НА!           КУЛТУРА           ! ВОДЕН  !ОПТИМАЛЕН!ДЕН ЗА НАПОЯВАНЕ!ПРОДУКТИВНА!  ПОЛИВНА   !КОЛИЧЕСТВО!
!        !=============================!ДЕФИЦИТ! ДЕФИЦИТ !================!   ВЛАГА   !   НОРМА    !   ВОДА   !
! ПОЛЕТО ! КОД!      НАИМЕНОВАНИЕ      !   ММ   !   ММ    ! НОМЕР !  ДАТА  !    ММ     !КУБ. М/ДКА!  КУБ. М  !
===========================================================================================================
!      1 !   6!   ЦАРЕВИЦА             !  13.2!    26.0 !    97 !  5/ 6  !    38.1   !   43.95  !      439 !
```

Figure 2. *Output from Scheduling program (original in Bulgarian)*

Institute "N. Poushkarov"

Computing Center

Date: 10/05/1977

METEOROLOGICAL DATA AND EVAPOTRANSPIRATION

DISTRICT: SOFIA AIC: EXPERIMENTAL FIELD LOCATION: CHELOPECHENE BEGINING DATE: 19/05

DAY		MEAN TEMPERATURE	RELATIVE HUMIDITY	SOLAR RADIATION	MEAN WIND SPEED	DEW POINT TEMPER.	NET RADIATION	HEAT FLUX	POTENTIAL ET
NUMBER	DATE								
80	19-May	18.35	75.0	455	4.30	13.32	240.2	11.55	5.8576
81	20-May	18.45	76.0	503	2.30	14.49	271.1	4.20	4.8876
82	21-May	19.40	69.0	480	2.70	13.86	254.3	9.60	5.6011
83	22-May	19.10	67.0	471	2.70	14.45	251.6	3.30	5.3853

Figure 3. *Output from Penman program (English translation)*

Institute "N. Poushkarov"

Computing Center

Date: 10/05/1977

SCHEDULE FOR PROGRAMMING IRRIGATION

DISTRICT: SOFIA AIC: EXPERIMENTAL FIELD LOCATION: CHELOPECHENE BEGINING DATE: 19/05

FIELD NUMBER	CROP		MOISTURE DEFICIT	OPTIMAL DEFICIT	DAY TO IRRIGATE		PRODUCTIVE MOISTURE	IRRIATION RATE	WATER QUANTITY
	CODE	NAME			NUMBER	DATE			
1	6	MAIZE	13.2	26.0	97	05-Jun	38.1	43.93	439

Figure 4. *Output from Scheduling program (English translation)*

The model for managing the irrigation regime considers two important related functions. The first is periodic forecasting the irrigation schedule, taking in account the specific soil, biophysical and meteorological conditions. The second function is periodically updating this irrigation schedule based on a 24-hour balance of income and expenditure quantities energy and water in the system "soil - plant sowing - atmosphere". Periodicity in both cases is three days.

Verification of the biophysical model was also done with respect to the dynamics of the water stock in the soil. Comparison of the average experimental values of the water stock in the soil with the calculated values on the base of the model is presented. As can be seen, the data obtained by both methods show a good coincidence. Therefore, it can be argued that the model correctly reflects the basic laws of the evapotranspiration process under the conditions considered.

In conclusion, it can be emphasized that the model under consideration is extremely useful, economical and effective. It cancels the periodic taking soil moisture samples and labor-intensive and expensive application of the thermostatic weighing method. Additionally, it gives the possibility of preliminary quantitative assessment of the irrigation schedule. Another particularly important advantage is the fact that the model gives integral values of evapotranspiration, water stock in the soil and other quantities for large-scale areas, while periodic soil moisture sampling is limited by place process. The possibilities of this approach for operational management of the irrigation regime on the scale of individual districts and aggregating country-wide information will provide a unified leadership on a scientific basis in this important branch of our agricultural practice and production.

Applications

We determined the irrigation schedules for maize (ARIS variety) and cotton (SINDOS-80) grown in the Experimental Field of the Institute at Sindos, Greece, in 1994, using the improved scientific basis and the corresponding software package, and carrying out periodical up-dating calculations (I. Christov et al., 1998). The application of the computer technology for irrigation scheduling in different geographical (soil, relief and climatic) conditions, is feasible. We can establish the dependencies of the crop yield amount and quality on the soil water status estimated by the index of soil-moisture energy levels for different regions. For this purpose, field experiments should be conducted in the future.

It is worth mentioning that on the issue of irrigation management there are a number of publications by Bulgarian authors (I. Varlev et al., 1995; I. Varlev, Z. Popova, 1999; I. Christov, 2004; A. Sadovski, 2018).

Conclusion

This brief paper summarizes over forty five years of progress in the development of modern methodology for scheduling irrigation in Bulgaria. The experience that I gained working with my college Prof. I. Christov over almost half century has been very rewarding personally. If I have emphasized my involvement too much it’s because I have been associated with the development of a Decision Support System, based on the sound scientific ground using mathematical models and algorithms, which deserve to be implemented in practice not only in my country, but also worldwide for more food, with less loss of non-renewable water resources and protection of our environment.

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Effect of Irrigation Water Quality on Soil Structure Along Asa River Bank, Ilorin Kwara State

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Abstract

Good soil structure is an essential element of healthy and sustainable agro-ecosystems. It promotes the development of extensive plant root systems and efficient use of water and nutrients. An experiment was carried out with the objective of evaluating the effect of irrigation water quality on soil structure, it was conducted in a two way factorial with four (4) locations selected along the river (0m, 200m, 400m and 600m) as factor A, and four (4) farmers' plots were selected based on the years of irrigation (0, 10, 20 and 30 years) as factor B while three (3) farmers plots with similar irrigation history were used as replicates, with this arrangement 12 plots were selected in each farming location giving a total of 48 plots from which soil samples were taken for analysis. The mean concentration of the parameters were pH (7.09-7.82), Electrical Conductivity {EC} (0.09-0.14), Sodium Adsorption Ration {SAR} (0.12-0.74) Exchangeable Sodium Percentage {ESP} (3.59-9.46), Sand (74.67-82.10), Silt (11.28-16.67), Clay (6.89-11.06), Mean Weight Diameter (1.38-1.53), Bulk density (1.12-1.29), Porosity (51.26-54.08), Saturated Hydraulic Conductivity (1.18-3.57). The mean concentration showed increase as the water flow downstream while higher value observed at location 3 (400m), the collected soil samples were subjected to analysis of variance using randomized complete block design (RCBD) at 5% probability level. The result showed that all the parameters were in a safe range when compared with WHO (2005) and FAO (2007) standard. It was recommended that effluent discharge and dumping of refuse along the river channel should be forcefully discouraged and that government should help in providing household disposal sites for the inhabitants of the town and that regular monitoring of Asa river be carried out as there is notable increase in the level of human and industrial activities along the course of the river.

Key words: Irrigation, Water quality, Soil structure, Asa River

Introduction

Irrigation can be described as the application of water to the soil to make available essential moisture for plant growth. It also serves as insurance against drought and to provide a cooling effect on the soil environment for plant growth and development. So, irrigation is aimed at improving and raising the productivity of soil resources. The principle, according to Handson (1999), is that the environment is characterized by fair to good soils but poor and unreliable irrigation water can cause advert effect on soil structure, soil properties as well as plant growth as it is the case in dry and semi-dry lands.

The quality of irrigation water (Salinity & Sodicity) has the potential to significantly affect soil structural properties (Levy and Miller, 1997). Saline irrigation water contains dissolved substances known as salts. In some arid and semi-arid regions, most of the salts present in irrigation water are chlorides, sulfates, carbonates, and bicarbonates of calcium, magnesium, sodium and potassium. While salinity can affect soil structure, it can also negatively affect plant growth and crop yields. Sodicity refers specifically to the amount of sodium present in the irrigation water. Irrigation with water that has excess amounts of sodium can adversely impact soil structure making it difficult for plant growth (Levy and Miller, 1997). Highly saline and sodic water qualities can cause problems for irrigation, depending on the type and amount of salts present, the soil type being irrigated, the specific plant species and growth stage, and the amount of water that is able to pass through the root zone. Under field conditions, irrigated soils are exposed to sequential periods of rapid wetting followed by drying. Soils which are subjected to these wetting and drying cycles have been found to exhibit low aggregate stability (Caron et al., 1992, Rasiah et al 1992.) resulting in the release of colloidal material and the collapse of soil pores (Levy and Miller, 1997). However, the quality of the irrigation water applied will also affect the soil chemical properties which influence soil dispersion and aggregate breakdown, surface sealing and crust formation (Schofield, 1955).

Khan et al., (2006) reported that the impact of irrigation water on soil structure seems certain to be very dependent, apart from the direct effects of rainwater alone, soil structure can be dramatically and rapidly degraded in other ways by irrigation. They also purported that the use of irrigation water of poor quality has a potential ability to inflict soil structural damage, in this regard, both adverse natural hydrology and poor irrigation water quality can independently degrade soil structure (and soil chemistry) by making the soil sodic which can also influence soil dispersion, aggregate breakdown, surface sealing and crust formation. The researchers further found that a SAR increased caused by irrigation water had an adverse impact on water infiltration, increasing sodicity and decreasing the concentration of applied water enhance physico-chemical dispersion. This dispersion, in turn, leads to a reduction in soil hydraulic conductivity.

According to Levy, (1992) and Naidu, (2003) the structural stability of soil is degraded dramatically by sodicity, a soil condition which promotes dispersion. They also recalled that the stresses that irrigation places on soil structure are amplified considerably when the irrigation water itself is of poor quality, water is a vehicle for the movement of vast amounts of salt in the landscape and irrigation has the capacity to transform a structurally stable soil into a salt-affected one. Salinity has a much more direct physical effect on soil structure as it is always due to high concentrations of sodium in irrigation water. The capacity of irrigation water to transform a non sodic soil into a sodic one depends upon a number of factors including soil type, management, and time and water quality. The water transmission capacity of any soil depends on the physical characteristics of the soil and how well it is managed. The physical characteristics are, themselves dependent on the structure or size distribution of mineral particles: on the structure or manner in which these particles are arranged: on the kinds of clay minerals present and the amount of exchangeable ions adsorbed upon them: and on the amount of organic matter incorporated with the mineral matter. In this study the characteristics of the soil are measured by various concepts such as salinity test, aggregate stability, bulk density, porosity, hydraulic conductivity among others. Good structure for crop growth depends on the presence of aggregate of soil particles 1-10mm which remain stable when wetted, such water stable aggregates will be porous so that they remain aerobic and yet possess sufficient numbers of pores to retain water for growth of plants (Tisdall and Oades, 1982). Therefore, detailed investigation regarding the effect of irrigation water quality on soil structure and its suitability for crops has no yet been done in the study area. Keeping these in mind, the present research reports the bench mark survey of irrigation water quality on soil structure Along ASA RIVER.

Objectives of the study

The main and specific objectives are:

To evaluate the effect of irrigation water on soil structure along Asa River

- To assess the effect of the use of Asa river water for irrigation on soil physico-chemical properties
- To determine long term use of Asa river water for irrigation on soil salinity
- To assess future effect of the use of Asa river for irrigation on soil and plant growth

Materials and Methods

Description of Experimental Location: A field research was conducted to evaluate the effect of irrigation water quality on soil structure along Asa rivier bank Ilorin.

Ilorin is the capital city of Kwara State. It is located by latitude 80 261N and longitude 40 301E with an area of about 100km2. The climate of Ilorin is characterized by wet and dry seasons, the rainy season normally begins at the end of March and last till November, the total annual rainfall ranges from 800 - 1,200mm in the northwest and 1,000- 1,500mm in the southeast (Oyegun, 1983). Daily temperature can be as high as 37oC just before the rainy season and as low as 21oC during harmattan (Oyegun, 1983).

According to (Eneudu, 1981) a large proportion of the land area along the river bank is dominated by Alluvial and Hydromorphic soils on the river savannah. The author also stated that a substantial area of the land is underlined by sedimentary rock, which contains both primary and secondary laterites and alluvial deposits, the soil type has both sandy and clayey deposits lying on top of each other, while the sandy deposits is characterized by low water holding capacity, which encourages infiltration, the clayey deposits beneath results in water logging during rainy season, thus encourages flood and runoff across the river bank.

The study areas covered selected portions of Asa river bank and are located at the Ilorin west local government. Asa river is the main river in Ilorin, the river flows in the South-north direction. It divides Ilorin into two parts: a western part representing the core or indigenous area and the eastern part where the Government Reservation Area (GRA) is located (Oyebanji, 1993).

Asa river is a major river of economic, agricultural and environmental significance in Ilorin—the capital city of Kwara State, Nigeria. The tributaries of Asa river in Ilorin are Agba, Aluko, Atikeke, Mitile, Odota, Okun and Osere. Adekunle (2008) and Adekola et al., (2007) observed that the river receives effluents from industries located along its course, apart from domestic wastes and other activities carried out along it that contribute to its pollution. They also reported that the major identified source of pollution of Asa river was direct runoff of effluents from the industries.

The research work was carried out at four (4) locations along Asa river bank used by farmers for dry season farming (vegetable production). The distances along the river bank corresponded with intervals in the river which serves as the farmers sources for irrigation water.

Field Studies

A total of 48 composite surface soil samples were collected from four (4) locations along the river bank at 200m distance which serve as Factor A while 10 years of history was used as Factor B for irrigation water. At each location 12 soil samples were taken from depth of 0-20cm and then bulk and stored for laboratory analysis, all samples were collected with the aid of stainless steel soil auger. Also 12 undisturbed soil core samples were taken from each location making a total of 48 core samples in all the four (4) locations. At each farming location three (3) farmers' plots with different irrigation history (0, 10, 20 and 30years irrigation duration) were selected while three (3) farmers' plots with similar irrigation history were used as replicates. With this arrangement 12 plots were selected in each farming location giving a total of 48 plots (4x4x3). All samples were collected and transported to the laboratory for the determination of physical and chemical soil quality parameters.

Laboratory Analysis

Bulked soil samples were air-dried and ground to pass through 2-mm sieve. Routine laboratory analysis was carried out to evaluate the physic-chemical properties of the soil as follows: The soil pH and EC (Electrical Conductivity) were determined in distilled water (1.2 soil/water) with a glass electrode pH meter and electrical conductivity meter. Soil particle size distribution was determined by hydrometer method (Bouyoucos, 1962) with sodium hexametaphosphate (calgon) as dispersing agent. Na was measured using flame photometer while Mg was determined by atomic absorption spectrophotometer. Ca content of the soil was determined by digestion in Nitric acid (HNO3) and perchloric acid (HClO4) in a 1:2. The Na, Mg and Ca determination were used to calculate Sodium Absorption Ratio (SAR).

Salinity Hazard Determination in the soil.

The Sodium Absorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) were used as indices of salinity hazard (U.S salinity laboratory staff, 1954). They were calculated thus:

$$SAR = \frac{Na^+}{\sqrt{(Ca+Mg)^{++}/2}}$$

$$ESP = \text{Exchangeable } \{(Na)/(Ca + Mg + K + Na)\} \times 100$$

Bulk density was analyzed using core method as proposed by Blake and Hartge (1986) while porosity was calculated from bulk density data assuming a particle density of 2.659gm-3, hydraulic conductivity and aggregate stability were determined according to the methods of Dane and Topp (2002).

Data analysis.

Data collected for soil sample were subjected to Analysis of Variance (ANOVA) using Genstat Discovery (Edition 4) statistical package and significant means were separated using the least significant difference (LSD) at 5% probability level.

Results and Discussion

Effect of distance of water and years of application on soil pH

Table 1 indicate that irrigation duration and the distance between points from which irrigation water was sourced had significant ($p<0.05$) effects on the mean soil pH value in the treated soils. The data obtained generally showed that the mean soil pH value increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources up to location three (400m downstream) with the lowest value (7.09) observed in location one (control) whereas the highest value (7.82) was observed in location three. There was a decrease in the mean soil pH value in location four (600m downstream). The significant increase observed at location two and three could be contribution of soluble salt from irrigation water. This agreed with the observation of (Schofield, 1955) who reported that increase soil pH could be contribution of soluble salt from irrigation water. While the decreased observed at location four could be as a result of dilution.

The mean effect of irrigation duration on soil pH value showed that soil pH increased significantly over intervals of 10years. The highest pH value of 7.58 was observed following 30years of the use of Asa river water for irrigation while the lowest 7.30 was observed on newly established farms without history of prior use of Asa river water for irrigation. The increased observed at 30years could be due to long term use of irrigation and continuous land cultivation. Comparing the value observed for pH in the soil, it fell within the permissible limits (6.5 – 8.5) by FAO (2007). However there is high tendency of the cultivated soil becoming alkaline as a result of intensive agriculture going on from year to year. Thus at high pH the concentration of heavy metals could reduce due to their insolubility, heavy metals has been found to be highly reduce at high pH as reported by McBride, (1994).

Table 1. *Effects of distance of water and years of application on soil pH.*

distance of Water (m) Factor A	**Years of application (years) Factor B**				**Mean**
	0	**10**	**20**	**30**	
0	7.01	7.05	7.14	7.19	7.09
200	7.02	7.07	7.17	7.20	7.21
400	7.67	7.80	7.83	7.97	7.82
600	7.24	7.30	7.50	7.70	7.44
Mean	7.30	7.33	7.38	7.58	

LSD $_{0.05}$, Factor A= 0.036, Factor B = 0.038, AXB = 0.182

Effect of distance of water and years of application on electrical conductivity (EC) in the soil.

Table 2 shows mean of EC values in soils treated with irrigation water from selected points along Asa river under various irrigation duration. The data obtained showed that the mean EC values increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources up to location three (400m downstream). The lowest value 0.09 dsm-^{1} was observed in location one (control) while the highest value, 0.14 dsm-^{1} was observed in location three. However, there was a decreased in the mean soil EC (0.12) in location four (600 downstream). The significant increase observed at location two and three could be as a result of proximity of these locations to the source of pollutant and the salt content from irrigation water, this is in agreement with the findings of Ayers and Westcot (1976). The mean effect of irrigation duration on soil EC values showed that soil EC values increased significantly over intervals of 10years. The highest concentration of 0.16dsm^{-1} EC in the soil was observed following 30years of the use of Asa river water for irrigation while the lowest 0.08 dsm^{-1} was observed on newly established farms without any history prior to the use of Asa river water for irrigation; this could be due to salt accumulation in the soil from irrigation water. The result of this analysis showed that the EC of the soil samples were found below the degree of restriction of uses (<0.7-3.0dsm-^{1}) Oster and Schroer (1979). However; if these areas are continuously cultivated and irrigated with this river water, it could increase soil salinity as well as sodicity and high EC value indicate that the osmotic pressure of the soil solution will increase which will affect plant yield by decreasing the water uptake and soil water availability (Provenzano, 2007).

Table 2. *Effects of distance of water and years of application on electrical conductivity (dsm^{-1}) in the soil.*

Distance of Water(m)Factor A	**Years of application (years) Factor B**				**Mean**
	0	**10**	**20**	**30**	
0	0.06	0.09	0.11	0.13	0.09
200	0.08	0.10	0.12	0.14	0.11
400	0.10	0.14	0.15	0.18	0.14
600	0.09	0.11	0.14	0.17	0.12
Mean	0.083	0.11	0.13	0.16	

LSD $_{0.05}$, Factor A= 0.012, B = 0.014, AXB = 0.016

Effect of distance of water and years of application on sodium adsorption ratio (SAR) in the soil.

Table 3 shows mean SAR in soils treated with irrigation water from selected points along Asa river under various irrigation duration. The data obtained showed that the mean SAR increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources up to location three (400m downstream). The lowest value of 0.12 was observed in location one (control) while the highest value of 0.74 (slight to moderate) was observed in location three. Thus, there was a decrease in the mean SAR in location four (600m downstream). The significant increase observed at location two and three could be contribution of salt content from irrigation water as a result of effluent discharge into the river used for irrigation. The decreased observed at location four could be as a result of leaching and or dilution the result shows none and or no harm to the soil Oster and Schroer (1979),

The mean effect of irrigation duration on the SAR of treated soil showed significant increase over intervals of 10years. According to the result of the analyzed soil sampled the highest value of 0.63 was observed following 30 years of the use of Asa river water for irrigation while the lowest value of 0.09 was observed on newly established farms without history prior to the use of Asa river water for irrigation. The result obtained could be attributed to the accumulation of salt in the soil as a result of long term use of irrigation water. This finding was also reported by (Hedeyasu, 2006). Moreover, the mean SAR of the soil sampled were found below (>3.0) FAO (1994), this implies that the river water is not saline and is not hazardous to soil for irrigation. SAR is an indication of salinity of the soil.

Table 3. *Effects of distance of water and years of application on SAR in the soil.*

distance of Water (m)Factor A	Years of application (years)Factor B				Mean
	0	10	20	30	
0	0.06	0.10	0.14	0.16	0.12
200	0.08	0.12	0.44	0.65	0.32
400	0.10	0.90	0.95	0.99	0.74
600	0.14	0.66	0.68	0.70	0.55
Mean	0.09	0.45	0.55	0.63	

LSD $_{0.05}$, Factor A = 0.021, B = 0.020. AXB = 0.031

Effect of distance of water and years of application on exchangeable sodium percentage (ESP) in the soil

The source of irrigation water along Asa river course and duration of irrigation was observed to significantly ($p<0.05$) increase the exchangeable sodium percentage (ESP) of treated soils (Table 4). The data obtained showed that mean treated values of ESP increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources up to location three (400m downstream) with the lowest value (3.59%) observed in location one (control) whereas the highest value (10.15%) was observed in location four. The significant increase observed at location two, three and four could be traced to the dissolve salt from irrigation water, as a result of contaminated water from different sources that drained into Asa river such as sewage sludge, kitchen waste and effluent from companies.

The mean effects of irrigation duration on ESP significantly increase over intervals of 10years. The highest ESP value of 10.71% was observed following 30years of the use of Asa River water for irrigation while the lowest 3.94% was observed on newly established farms without history of prior use of Asa river water for irrigation. This indicates accumulation of salt (sodium) due to long term use of Asa river for irrigation, similar result was observed by (Hedeyasu, 2006). The result obtained fell below the critical limit by Reev *et al*, (1954) and Majid, (2009), who reported that when the ESP in the soil is 15%, then the soil is sodic. This implies that the soil is free from sodicity (excess sodium). Similar result was observed by Sharinberg, (1994).

Generally the use of Asa River water in location three (400m downstream) for 30years showed the highest significant increase (13.60%) in the soil ESP concentration. This could be as a result of long term use of irrigation water

Table 4. *Effects of distance of water and years of application on ESP % soil.*

distance of Water (m)Factor A	Years of application (years)Factor B				Mean
	0	10	20	30	
0	2.01	2.80	4.70	4.83	3.59
200	2.07	3.40	11.83	12.60	7.48
400	3.23	8.80	12.20	13.60	9.46
600	8.45	10.10	10.23	11.80	10.15
Mean	3.94	6.28	9.74	10.71	

$LSD_{0.05}$,
Factor A = 0.220
Factor B = 0.091
AXB = 0.320

Effect of distance of water and years of application on soil particle analysis in the soil

Table 5-7 indicate that irrigation duration and the distance between points from which irrigation water was sourced had significant ($p<0.05$) effects on the mean sand in the treated soils. The data obtained showed That the mean of sand, silt and clay increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources up to location three (400m downstream) with the lowest value (74.67%) for sand, (11.28%) for silt and (6.89%) for clay were observed in location one (control),whereas the highest value (84.91%) for sand, (19.86%) for silt and (11.06%) for clay was observed in location four.

The average values of percentage sand silt and clay reveals a loamy sand and sandy loamy texture in all the experimental locations. The loamy sand texture was found from 0m (control) till 200m distance at 20 years of irrigation. Consequently; the percentage sand content of the soil has the highest value of 86.24% at 10 years of irrigation while clay content of the soil has 5.71% lowest value at 30 years of irrigation following 0m (control).

Table 5. *Effects of Distance of water and years of application on sand (%) in the soil.*

Distance of water (m)	Years of application (years)				Mean
	0	10	20	30	
0	78.45	73.91	75.40	70.24	74.67
200	75.65	86.24	85.91	72.57	80.09
400	72.34	87.91	71.91	83.24	82.10
600	74.24	80.57	79.24	82.24	81.91
Means	74.17	76.91	72.62	77.07	

LSD0.05, Factor A=2.04, Factor, B=2.67, AXB = 3.35

The textural classes were mainly loamy sand at the two locations, this could be the appropriate soil surface or the required topsoil for plant growth which agrees with the findings of Nwa and Ogunase (1983) who reported that loamy sand was suggested as the soil surface layer otherwise, disperse or breakdown by chemical or tillage forces, except at 30years of location two (200m) which had textural class of sandy loam which could be traced to the dispersing fraction of the soil as a result of high sodium content and or breakdown of soil structure as a result of poor irrigation water, this was the same at location three (400m) and location four (600m).

Table 6. *Effects of Distance of water and years of application on silt (%) soil.*

Distance of water (m)	**Years of application (years)**				**Mean**
	0	**10**	**20**	**30**	
0	11.65	15.70	13.85	14.50	11.28
200	14.75	17.67	17.00	17.00	13.40
400	15.00	19.67	20.70	21.20	16.67
600	13.25	17.00	23.67	23.33	19.86
Means	14.38	14.34	16.92	15.58	

LSD0.05, Factor A=2.61, Factor B=2.49, AXB = 2.98

Table 7. *Effects of Distance of water and years of application on clay (%) soil.*

Distance of water (m)	**Years of application (years)**				**Mean**
	0	**10**	**20**	**30**	
0	8.95	7.43	6.44	4.76	6.89
200	9.85	8.08	7.09	10.43	8.61
400	12.66	11.41	12.09	7.76	10.98
600	11.08	9.09	14.31	9.76	11.06
Means	9.18	8.75	11.44	8.78	

LSD0.05, Factor A=1.22, Factor B=1.03, AXB = 2.06

Table 8. *Particle sizes showing the textural class of the soils.*

Location (m)	Samples (years)	Sand %	Silt %	Clay %	Textured Class
0	10	80.24	12	7.76	LS
	20	78.00	15	6.76	LS
	30	82.24	12	5.76	LS
200	10	86.24	6.7	7.0	LS
	20	85.41	7	7.0	LS
	30	72.8	17	10.7	SL
400	10	66.7	21.7	11.41	SL
	20	66.7	21	12.1	SL
	30	66.6	21.6	11.8	SL
600	10	73.7	17	9.0	SL
	20	65.24	23.7	11.1	SL
	30	70.24	23.1	9.76	SL

LS = Loamy sand SL = Sandy loam

Effect of distance of water and years of application on mean weight diameter (MWD) in the soil

Table 9 indicate that irrigation duration and the distance between points from which irrigation water was sourced had significant ($p<0.05$) effects on the mean weight diameter. The data obtained showed that effect of change in distance between water sources on mean weight diameter (MWD) of soil aggregate increased significantly ($p<0.05$) at location one and four but decreased in location two and three respectively. The decrease observed in location two and three could be attributed to the accumulation of sodium salts contained in the irrigation water over time in the soil causing dispersion of soil aggregates.

The mean effect of irrigation duration on mean weight diameter (MWD) of soil aggregates showed decrease over intervals of 10years. The highest mean of 1.56mm was observed on newly established farm (0year) without history of prior use of Asa river water for irrigation while the lowest 1.33mm was observed at 30years, the significant increased observed at 0year could be attributed to the fact that the soil has not been disturbed with constant irrigation and cultivation making the aggregate of soil particles remain stable when wetted given the soil a larger pores for favorable aeration and good drainage as well as good stability than others before the commencement of irrigation application and farming activity , while the lowest value observed at 30years could be impact of salt content from irrigation water leading to little dispersion and structure deteriorated in the soil, Ayers and Westcot, (1976) reported that all irrigation water contains dissolved mineral salts weather big or small. Also the reduction observed at 30years of irrigation duration could be as a result of constant land cultivation leading to the breakdown of soil aggregate stability. However the mean weight diameter of the study soil was under good structure for crop growth when compared with the finding of Tisdall and Oades, (1982) who reported that aggregate of soil particles between 1- 10mm diameter remain stable when wetted, thus providing good structure for crop growth.

Table 9. *Effects of distance of water and years of application on mean weight diameter (mm) in the soil.*

distance of Water (m)Factor A	**Years of application (years)Factor B**				**Mean**
	0	**10**	**20**	**30**	
0	1.53	1.56	1.52	1.51	1.53
200	1.55	1.50	1.26	1.20	1.39
400	1.57	1.43	1.36	1.30	1.38
600	1.59	1.54	1.40	1.29	1.42
Mean	1.56	1.45	1.37	1.33	

LSD $_{0.05}$, Factor A = 0.166, B = 0.06, AXB = 0.129

Effect of distance of water and years of application on soil bulk density

The source of irrigation water along Asa river course and duration of irrigation was observed to significantly ($p<0.05$) increase the bulk density of the soils (Table 10). The data obtained showed that mean bulk density value increased significantly ($p<0.05$) for every 200m increase in distance between irrigation water sources with the lowest value (1.12g/cm^3) observed in location one (control) whereas the highest value (1.29g/cm^3) was observed in location four.

The mean effect of irrigation duration on soil bulk density showed significant increase over intervals of 10years. The highest bulk density value of 1.35g/cm^3 bulk density in the soil was observed following 30years of the use of Asa river water for irrigation while the lowest value of 0.99g/cm^3 was observed on newly established farms without history of prior use of Asa river water for irrigation. The highest value observed at 30years of irrigation could be attributed to continuous cultivation; this agreed with the finding of Adeoye, (1983) who reported that continuous land cultivation could increase bulk density. However the result observed showed that the bulk density is in safe range when compared with the standard given by Grossman *et al*, (2002) who stated that bulk density >1.6 g/cm^3 is not safe and at the level of compaction.

Table 10. *Effects of distance of water and years of application on soil bulk density (g/cm^3)*

distance of Water (m)Factor A	Years of application (years) Factor B				
	0	**10**	**20**	**30**	**Mean**
0	0.9	1.03	1.27	1.30	1.12
200	1.00	1.23	1.32	1.34	1.22
400	1.02	1.33	1.38	1.37	1.27
600	1.03	1.20	1.24	1.40	1.29
Mean	0.99	1.19	1.30	1.35	

LSD $_{0.05}$, Factor A = 0.04, B = 0.02, AXB = 0.064

Effect of distance of water and years of application on soil porosity

Table 11 indicate that irrigation duration and the distance between points from which irrigation water was sourced had significant ($p<0.05$) effects on soil porosity. The data obtained showed that soil porosity increased significantly ($p<0.05$) at interval of 200m respectively. The lowest value of (51.26%) was observed in location one whereas the highest value (54.08%) was observed in location four.

Table 11. ***Effects of distance of water and years of application on soil porosity (%)***

distance of Water (m)Factor A	Years of application (years)Factor B				
	0	**10**	**20**	**30**	**Mean**
0	50.04	52.14	52.40	54.47	51.26
200	51.12	54.90	51.44	52.62	52.52
400	52.14	53.60	50.14	50.53	53.60
600	54.14	51.54	51.20	56.44	54.08
Mean	50.86	52.26	53.29	54.26	

LSD $_{0.05}$, Factor A = 2.028, B = 2.144, AXB = 3.021

The mean effect of irrigation duration on soil porosity concentration showed increase over intervals of 10years. The highest total porosity of 54.26% was observed following 30years of irrigation water while the lowest 50.86% was observed on newly established farm 0year, the significant increase observed at 30years of irrigation could be due to activities of micro-organisms which open the top soil or broken-down of soil particles as a result of continuous cultivation over time. Thus the total porosity is in control when compare with the report of Oliver (1997) that the total porosity is low below 45%.

Saturated hydraulic conductivity (Ks)

Table 12 revealed the result of Ks .The data obtained showed that Ks increased significantly ($p<0.05$) at interval of 200m respectively. The lowest value of (1.18 cmh^{-1}) was observed in location one whereas the highest value (3.57cmh^{-1}) was observed in location four.

The mean effect of irrigation duration on Ks showed that Ks increase over intervals of 10years. The highest Ks 3.20 cmh^{-1} was observed at 30years while the lowest 2.16 cmh^{-1} was observed at 0year, the highest Ks obtained at 30years could be due to cultivation which encourage the activity of micro-organisms Nwa and Ogunase (1983).

Table 12. *Effects of distance of water and years of application on saturated hydraulic conductivity (cmh^{-1}) in soil*

Source of Water (m)Factor A	**Irrigation Duration (years)Factor B**				**Mean**
	0	**10**	**20**	**30**	
0	1.03	1.01	1.33	1.35	1.18
200	2.06	3.33	2.36	3.70	2.86
400	2.85	3.47	3.57	3.80	3.42
600	2.70	3.75	3.87	3.97	3.57
Mean	2.16	2.62	2.78	3.20	

LSD $_{0.05}$, Factor A = 0.184, Factor B = 0.151, AXB = 0.24

Conclusion

Asa river supplies the basic water needs of Ilorin and its environs after treatment at Asa Dam treatment plant. Shortage of sufficient potable water has led many people to depend on this river not only for drinking but also, for other domestic, agricultural and industrial uses, therefore, its quality and pollution status is thus of serious concerns that worth investigation and assessment.

The sources of pollution identified above causes the pollution of Asa river as reported by different authors, but no research work has been done on the effect of the river water use for irrigation on soil structure. This brought out the need to assess the quality of Asa river for irrigation. Parameters such as EC, pH, SAR, and ESP were investigated in the soil as physic-chemical properties while physical properties such as Aggregate stability, Bulk density, Total porosity and saturated hydraulic conductivity were also investigated from which all the parameters were found in safe range as approved by FAO (1989) and WHO (1996, 2005), the collected soil samples were subjected to analysis of variance using randomized complete block design (RCBD).

The sodium concentration in soil for EC, SAR and ESP were found below standard as approved by different agencies, as well as the physical parameters. This shows that, the condition of soil structure across the river bank is in a good state and is therefore good for dry season irrigation farming. However there is high tendency of the cultivated soil along the river bank becoming alkaline and or sodic/saline as a result of intensive agriculture through application of irrigation water for moisture content going on from year to year. But proper treatment of effluent discharge into the river should be done by each company before released into the river as long term accumulation of these chemical and or heavy metals could pose a potential treat to soil health.

It is therefore recommended that effluent discharge and dumping of refuse along the river channel should be forcefully discouraged and that government should help in providing household disposal sites for the inhabitants of the town and that regular monitoring of Asa river be carried out as there is notable increase in the level of human and industrial activities along the course of the river. Finally it is also recommended to coordinate different efforts at the level of the community dwellers and the government to rescue the downstream of Asa river from the current hazard- posing environmental problems.

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Potentials of Soils derived from Asu River Group and Asata Nkporo Shale for Arable Crop Production in Ebonyi State, Nigeria.

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Abstract

Land capability classification (LCC), fertility capability classification (FCC) and land suitability evaluation of some soils of Ebonyi State were carried out for cassava, yam and maize cultivation. Land capability and fertility capability classes were obtained using the method of United State Development of Agriculture (USDA) while suitability evaluation was done using the Food and Agricultural Organization of the United Nations' (FAO) conventional method. Four (4) pedons were investigated, two from Akaeze (Asu river group) and two from Abakaliki (Asata nkporo shale) . Results of LCC showed that sites 1 and 2 (Asu river group) were classified as class II soils while sites 3 and 4 (Asata nkporo shale) were classified as class IV soils. According to FCC results, the major classes obtained were SM,g,k for site 1, A,g,k for site 2 and SA,e,k,r for sites 3 and 4 respectively. The results of land suitability evaluation showed that despite climatic factors and topography, there was no highly suitable (S1) land for maize, yam and cassava cultivation. Total nitrogen and organic carbon contents of pedons 1, 2 and 4 were marginally (S3) suitable for the production of yam and cassava while the nitrogen and organic carbon contents of pedon 3 were currently not suitable (N1) for yam and cassava cultivation. Soil texture, pH, ECEC and available phosphorus made the 4 sites moderately suitable (S2) for cassava and yam cultivation. Also, the acidic condition of the soils made all the sites moderately suitable for maize production. From the results of the aggregate suitability ratings, the major constraint for yam, cassava and maize cultivation in the sites was soil fertility (f) resulting from low organic carbon and total nitrogen contents of the soils. Though not optimum for the cultivation of the crops evaluated, the soils can still produce increased and sustainable crop yield if the appropriate husbandry practices are adopted, with particular reference to organic and nitrogen fertilizer application.

Key words: Arable crop, Fertility capability classification, Land capability classification, Land suitability evaluation.

Introduction

Nigeria is the most populous country in Africa with about 140 million citizens (NPC, 2006); approximately, 70 million are rural dwellers. Most rural residents are engaged in smallholder semi-subsistence agriculture (Ajibolade, 2005), therefore, agriculture remains a crucial sector in the Nigerian economy, being a major source of food, raw material as well as foreign exchange, employing over 70 percent of the Nigerian labor force, and serving as a potential vehicle for diversifying the Nigerian economy and enabling economic development. However, the creation of Ebonyi State in 1996, stimulated efforts to improve agriculture and rural development in Nigeria. Ebonyi State has a land mass of approximately 5,952 square kilometers (EBMOI, 2005) and a population of 2.1 million people, constituting about 1.55% of the country's population (NPC, 2006). The major occupation of the people of Ebonyi is subsistence farming with food crops dominating the practice. The agricultural type is mainly the mixed farming where food crops predominantly planted are cassava, yam, maize and rice. Generally, food crop production in Ebonyi State has been continuously practised without adequate information on land use practices. In order to avoid the drastic consequences of inappropriate land use practices, there is the need for information on the quality of land/soils in prime agricultural areas in Nigeria. The lack of comprehensive soil map indicating soil types and nutrient requirements of each crop has led to the indiscriminate application of mineral fertilizers, which poses more risk on the fragile soils (Ayeni, 2011).

Land/soil evaluation describes the characteristics of the land/soils in a given area, classifies them according to a standard system of classification, plots boundaries of the land/soils on a map and make predictions about the behaviour of the land/soils (USDA, 1993). The information helps in the development of land use plans, evaluates and predicts the effects of land use on the environment (Shepande,2002). The objectives of most soil survey investigations are to provide data for the rational planning and adjustment of land use (Hubrechts et al., 2004). Optimum crop production can be achieved through the rational use of fertilizers accompanied with other management practices that take cognizance of the variability of the soils (Omotosho and Akinbola, 2007). The shortage of prime land in some cases have led to land use and environmental conflicts. The knowledge of the pattern of land/soil distribution and the characteristics of each unit of land/soil are very essential for a better understanding, use and management of soils/lands (Nuga and Akinbola, 2011). In the face of these disturbing realities, the major objective of this study was to evaluate the potentials of soils of Akaeze and Abakaliki in Ebonyi state for the cultivation of maize, yam and cassava.

Materials and Methods

Description of the Study Area

The study was carried out at two (2) different locations namely, Afikpo North and Akaeze (Latitudes 5° 30^1, 5° 9^{1}N and Longitudes 5° 5^1, 7°.6^1 E) in Ebonyi State, South-east Nigeria. The lithological materials from which the soils of the areas were developed are Asata nkporo shale (Afikpo) and Asu River group (Akaeze). Generally, Ebonyi State falls within the tropical rainforest zone of South-east Nigeria with a humid tropical rainfall range of 1500 mm to 2500 mm. The average annual atmospheric temperature ranged from 26°C to 30°C (NIMET, 2014). It has a land mass of approximately 5,952 square kilometers (EBMOI, 2005) and a population of 2.1 million people (NPC, 2006). The major occupation of the people of Ebonyi is subsistence farming with food crops dominating the practice. The agricultural type is mainly the mixed farming where food crops predominantly planted are maize, cassava, yam and rice.

Soil Sampling and Laboratory Analysis

Reconnaissance field trip was undertaken and routine materials and methods to be used in the field study were noted. With the aid of a geological map of the area, the two sampling areas (Akaeze and Abakaliki) were selected randomly. Four (4) pedons were dug (two in each site), described and sampled according to the procedure of FAO, (2006) and Soil Survey Staff, (2006). Samples were collected based on horizon differentiation from the pedons.. Three representative soil samples were collected from each of the various identified genetic horizons of the soil profiles for laboratory analyses. The soil samples were air-dried, crushed and made to pass through 2.0 mm mesh sieve. Samples were also collected with core samplers for bulk density analysis. Particle size analysis was performed using the Bouyoucous hydrometer method (Gee and Or, 2002). Bulk density was determined using the core method as described by (Gross and Reinsch 2002). Exchangeable base cations (Ca, Mg, K, and Na) were extracted with 1 N NH4OAc (pH 7) (Thomas, 1996). Exchangeable calcium and magnesium were determined by EDTA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry. Effective Cation Exchange Capacity (ECEC) was calculated by the summation of the total exchangeable bases and total exchangeable acidity. Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982) while total nitrogen was determined by the method of Bremner and Mulvaney (1982). Available phosphorus was determined by Bray-II method (Olsen and Sommers 1982). Soil pH was measured potentiometrically in water at the soil-liquid ratio of 1:2.5 (Thomas, 1996).

Land Evaluation and Data Analysis

Means of the data generated from soil laboratory analyses were calculated. FCC was done according to USDA fertility capability classification system modified by Sanchez et al., (2003) while LCC was done according to USDA Land Capability Classification System (Klingebiel and Montgomery, 1961). Land suitability evaluation was carried out using the FAO (1976); modified by Sys, (1985; 1991) guidelines for land evaluation. Key environmental factors considered in the evaluation were climate (annual rainfall and temperature), topography (slope) and soils. The criteria employed for the evaluation of soils were soil depth, soil texture, drainage, pH, available P, organic carbon, total N, effective CEC, and base saturation. The identified soil units were placed in suitability classes by matching their characteristics with the requirements of the test crops. The most limiting characteristic dictated overall suitability for each soil. The suitability of each factor for each soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and currently not suitable (N1).

Results and Discussion

Physical and Chemical Properties of Soils

Considering the two soil groups investigated, the average sand content ranged from 34.40 -35.40% (Asu river group) and 75.4 -76.00% (Asata nkporo shale). The four pedons had mean silt content range of 39.20 and 40.60% with 39.20, 40.60, 7.20 and 6.00% for pedons 1, 2, 3 and 4 respectively (Table 1).

Table 1. *Land/Soil Characteristics of the Sites.*

Land characteristics	Pedon 1	Pedon 2	Pedon 3	Pedon 4
Climate (c)				
Annual rainfall (mm)	1700-2250	1700-2250	1700-2250	1700-2250
Relative humidity (%)	70 – 85	70 – 85	70 – 85	
Temperature (°C)	24-30	24-30	24 -30	
Topography (t)				
Slope (%)	0-1	0-1	4	4.5
Soil physical characteristics				
Wetness (w)				
Drainage	2-3	2-3	1	1
Bulk density (g/cm^3)	1.49	1.45	1.42	1.25
Sand (%)	35.40	34.40	75.40	76.00
Silt (%)	39.20	40.60	72.00	60.00
Clay (%)	25.36	24.94	17.36	17.36
Texture	SCL	SL	SL	SL
Soil depth (cm)	122	128	137	115
Soil fertility (f)				
Ca (cmol$_{+/}$kg)	5.06	3.34	0.96	0.74
Mg (cmol$_{+/}$kg)	3.12	3.36	1.37	1.04
K (cmol$_{+/}$kg)	0.03	0.01	0.006	0.005
Na (cmol$_{+/}$kg)	0.01	0.01	0.01	0.01
ECEC (cmol$_{+/}$kg)	12.98	12.87	3.41	11.51
BS (%)	65	52	67	44
Organic carbon (g/kg)	6.85	6.74	3.99	4.71
pH	5.91	5.97	5.67	5.70
Total nitrogen (g/kg)	0.65	0.66	0.41	0.51
Av. Phosphorus (mg/kg)	10.12	8.92	8.34	20.74

Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, SCL = Sandy clay loam, SL = Sandy loam

The average clay content ranged between 17.36 and 25.36%; with pedon 1 having a mean value of 25.36%, whereas pits 2, 3 and 4 had mean values of 24.96, 17.36, and 17.36% respectively (Table 1). The textural class of the soils of the Asu river formation comprised generally of sandy clay loam, loam and sandy loam while the textural class of the soils of the Asata nkporo shale comprised of sand, sandy loam and loamy sand. However, the sand, silt and clay fractions of the soils and their textural class generally represent soils of the area as was shown by previous studies (Ande *et al*., 2016; Tijani *et al*., 1996). Results showed that mean bulk density values ranged from 1.49 - 1.45 g/cm^3 in pedons underlain by Asu river group and 1.42 -1.25 g/cm^3 in pedons underlain by Asata nkporo shale. The mean bulk density values of the two soil groups fall within the range that is expected of tropical soils.

Table 2. *Land Capability Classification (LCC) of Soils.*

Soil group	Class	Limitations
Asu river group		
Pedon 1	Class II,w	Wetness
Pedon 2	Class II,w	Wetness
Asata nkporo shale		
Pedon 3	Class IV,r,s	Rock outcrop, slope
Pedon 4	Class IV,r,d,s	Rock outcrop, depth, slope

w = wetness, r = rock outcrop, d = shallow depth, s = slope

The pH data showed that soils were moderately acidic in water with mean pH values ranging from 5.92 and 5.97 in soils derived from Asu river group; 5.67 and 5.70 in those derived from Asata nkporo shale respectively. Onwudike *et al*. (2016) and Olabode, O.S (1997) reported similar pH values in some soils of Nigeria. Abua *et al*. (2010); attributed soil pH of an area to the nature of the parent material, climate of the region, organic matter and topographic situations. The acidic nature of the soils investigated could be attributed to the high rainfall resulting in the leaching of some base-forming cations especially from the surface horizons of the soils. Organic carbon content of the soils was generally low. Highest organic carbon values (6.85 and 6.74 g/kg) were recorded in profiles 1 and 2 of Asu river group. On the other hand, organic carbon content of soils of the Asata nkporo shale ranged from 4.712-3.99 g/kg. Average total nitrogen (TN) content of the soils was very low (< 0.66 g/kg) in all the pedons investigated. The low nitrogen concentration is a common phenomenon in the soils of Southeastern Nigeria and is as a result of the high nitrogen losses sustained in these soils through the leaching of nitrates, as well as the rapid mineralization of organic matter under the isohyperthermic soil temperature regime (Ahukaemere, 2015). The available phosphorus content of the soils of the Asata nkporo shale (20.75 – 8.34 mg/kg) was relatively higher than those of the Asu river group (10.12 – 8.92 mg/kg). However, the available phosphorus concentration in soils of the Asu river group was moderate while that of Asata nkporo shale was rated medium to high since (Beerneart and Bitondo, 1992) reported the critical P values as < 5, 5-15 and >15 mg/kg for low, medium and high respectively.

Exchangeable calcium values ranged from 3.34 – 5.06 cmol+/kg in soils of the Asu river group and 0.96 – 0.74 cmol+/kg in soils of the Asata nkporo shale. However, soils of Asata nkporo shale were acutely deficient in calcium compared to those of Asu river group indicating less leaching losses in these soils. Exchangeable magnesium was higher than the critical value of 1.2 cmol+/kg (Esu, 1999) in all the soils. The low calcium concentration in soils of the Asata nkporo shale can be attributed to the acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition of the region (Eshett *et al.*, 1988). Exchangeable potassium concentration was extremely low (< 0.3 cmol+/kg). Idigbor *et al.* (2008) attributed the low potassium concentration in the soils of South-eastern Nigeria to the fact that there is generally a low potassium reserve in acid soils. This could be attributed to the highly mobile nature of exchangeable potassium relative to calcium and magnesium and its consequent massive loss through leaching (Thompson, 1957).

Table 3. *Fertility Capability Classification (FCC) of soils.*

Soil group	Fertility class/limitations
Asu river group	
Pedon 1	SM,g,k
Pedon 2	A,g,k
Asata nkporo shale	
Pedon 3	SA,e,k,r
Pedon 4	SA,e,k,r

S = sandy top soils, M = Fine loamy subsoil, A = Coarse loamy topsoil and subsoil, g = gley, k = Potassium deficiency, e = low CEC (ECEC), r= rock or root restricting layer.

Land Capability Classification of the Sites

The Land Capability Classification (LCC) of the two investigated soil groups are shown in Table 2. Soils derived from the Asu river group as shown in profile pits 1 and 2 were classified as class II soils according to USDA Land Capability Classification System (Klingebiel and Montgomery, 1961). The soils of Asu river group have some limitations that reduce the choice of crops or require moderate conservation practices. Generally, the limitations of soils in this class include the effect of gentle slopes, moderate susceptibility to erosion, less than ideal soil depth, somewhat unfavourable soil structure, occasional damaging overflow, wetness correctable by drainage. These soils require more than ordinary management practices for obtaining optimal production and for maintaining productivity. However, Obasi *et al*., (2014) noted that farmers in these regions have subjected large area of this soil group into lowland rice farming, while the adjacent uplands are used for cassava, maize and yam production.

Table 4. *Land Requirements for Cassava.*

	Factor suitability rating			
Land Qualities /characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Climate (c)				
Annual rainfall (mm)	1100-1500	900-1100	500-900	<500
Temperature (^{o}C)	18-30	12-18	<12	Any
Soil physical characteristics (s)				
Soil depth (cm)	>100	100-75	50-75	< 50
Soil texture	L, SC, CL	LS, SiCL, SL	Sand, SiC	Clay
Topography (t)				
Slope (%)	0-5	5-12	12-20	>20
Wetness (W)				
Drainage	1	2-3	4	5
Soil Fertility Status (f)				
pH	6.1-7.3	5.1- 6.0 or 7.4-7.8	<4.0 or >8	Any
Total N (g/kg)	> 2.0	1.0-2.0	<1.0	Any
Av. P (mg/kg)	>25	6-25	<6	Any
Organic C.(g/kg)	>20	15-20	8-15	<8
Ex. K (cmol$_{+/}$kg)	>6	3-6	<3	Any
ECEC (cmol$_{+/}$kg)	>16	3-16	<3	Any
Base saturation (%)	>35	20-35	<20	Any

Source: Source: Sys *et al.* (1991).

Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, L = loam, CL = clay loam, SC = sandy clay, SiC = Silty clay, LS = loamy sand

Land Capability Classification of soils of Asata Nkporo Shale group reveals a Class IV soils (Klingebiel and Montgomery, 1961), as shown in profile pits (sites) 3 and 4 (Table 2). Class IV soils have very severe limitations that restrict the choice of plants and or require very careful management practices. Restrictions, both in terms of choice of crops and or management and conservation practices are greater in Class IV to such an extent that production is often marginal in relation to the inputs required. Limiting factors are of the same nature as in the previous classes but more severe and difficult to overcome. Several limitations such as steep slopes, shallow depth, rock outcrops are permanent features of the sites. Some of the limitations due to sloppiness and erosion hazards in classes II to IV can be reduced by biological terracing as practised in agroforestry and alley cropping. However, in the USDA LCC system, soils of classes II-IV are moderately suitable for cultivation with minor to moderately severe limitations and require management practices while soils of classes V to VIII are generally not suitable for cultivation, although certain of them may be made suitable for agricultural use with costly measures.

Fertility Capability Classification of the Sites

The fertility capability classes of the investigated soils are shown in Table 2. Asu river group site 1 (pedon 1) had a sandy topsoil (Type) and sandy clay loam subsoil (Subtrata Type) in their textural composition. Asu river group site 2 (pedon 2) had sandy loam as both topsoil and subsoil texture within the 50 cm depth. The major limiting factor of soils of Asu river group was drainage as the sites experience saturation with water for 60 or more consecutive days in most years. Also, there is K deficiency as exchangeable K was < 2% of the summation of bases. The summation of bases, 8.23 cmol+/kg of soil (site1) and 6.72 cmol+/kg of soil (site 2) were very low when compared to100 cmol+/kg acceptable limits (Sanchez *et al*.., 2003). The Fertility Capability classification (FCC) of Asata nkporo shale group as shown in Table 3 indicated that sites 3 and 4 had a sandy topsoils (S) and coarse loamy subsoil (A). The limitations of soils of this group include very low CEC (e) 3.41cmol+/kg (site 3) and 4.06 cmol+/kg (site 4) as Sanchez *et al*.., (2003) acceptable limits of CEC is 40 cmol+/kg. The soils of Asata nkporo group also showed the presence of rocks (r) which may cause root restriction within the 50 cm depth. Quang, (2011) suggested that the use of mineral fertilizers is not recommended in these soils in their natural state, as nutrients are not retained by soils with low CEC (e) due to the low capacity to retain nutrients. In addition, leaching causes big nutrient losses when lime and fertilizers are applied; therefore, heavy applications of these nutrients and of N fertilizers should be split. Organic matter application is also recommended to increase soil cation exchange capacity. Low Nutrient Capital Reserves (k), Potassium fertilizers must be added. Generally, these soils have also the limited capacity to retain nutrients and the potassium, calcium and magnesium added can be easily lost (Nguyen, 2003).

Suitability Classification of the Soils for Cassava and Yam Production

Tables 4 and 5 showed the land requirement for cassava and yam as described by Sys et al. (1985 and 1991). When land requirements of the test crops were matched with the land quality of the studied sites (Table 1), all the soils were highly suitable in terms of climatic and slope requirements for yam and cassava production (Table 7).

Table 5. *Land Requirements for Yam.*

	Factor suitability rating			
Land Qualities /characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Currently not suitable (N1)
Climate (c)				
Annual rainfall (mm)	>800	800-500	<500	Any
Temperature (^{o}C)	18-29	15-18	12-15	<12
Relative humidity (%)	>75	75-65	<65	
Soil physical characteristics (s)				
Soil depth (cm)	Deep (>75)	60-75	40-60	< 40
Soil texture	LS	SL, SCL	Sand, SiC, CL	Clay
Topography (t)				
Slope (%)	< 4	4-8	>8	>20
Wetness (W)				
Drainage	1	2-3	4	5
Soil Fertility Status (f)				
pH	6.1-7.3	5.1- 6.0 or 7.4-7.8	<4.0 or >8	Any
Total N (%)	> 1.5	1.0-1.5	1.0-0.5	<0.5
Av. P (mg/kg)	>25	6-25	<6	Any
Organic C (%)	>20	15-20	8-15	<8.0
Ex. K (cmol$_{+/}$kg)	>6	3-6	<3	Any
ECEC (cmol$_{+/}$kg)	>16	10-16	3-10	<3
Base saturation (%)	>35	20-35	<20	Any

Source: Sys *et al* (1991), Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained, CL = clay loam, SL = sandy loam, SiC = Silty clay, LS = loamy sand

These results indicated that the study area is currently ideal in terms of climate for the cultivation of both crops. Some works done in south-east Nigeria showed that the climatic condition of the area is ideal for the production of most arable crops (Ahukaemere *et al*., 2015; Ajiboye and Olaniyan, (2016); Udoh *et al*., 2011; Nuga and Akinbola, 2015). Similarly, the depth and base saturation of the soils made the sites highly suitable (S1) for the cultivation of both crops.

Table 6. *Land requirements for Maize.*

	Factor suitability rating			
Land Qualities/characteristics	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Currently not suitable (N1)
Climate (c)				
Rainfall (mm)	>800	700-800	600-700	<600
Temperature (^{o}C)	24-30	20-24	15-20	<15
Soil physical characteristics (s)				
Soil depth (cm)	>120	75-120	30-75	< 30
Soil texture	CL,L	SL, LS	LCS	CS
Topography (t)				
Slope (%)	0-2	4-8	8-16	>16
Drainage	Well drained	Moderately drained	Imperfectly drained	Poor
Soil fertility status (f)				
pH	6.0-6.5	5.5-6.0	5.0-5.5	< 5.0
Total N (g/kg)	>1.5	1.0-1.5	0.5-1.0	< 0.5
Available P (mg/kg)	>40	10-40	3-10	< 3
CEC (cmo1$_{+}$/kg)	>25	13-25	6-13	< 6
Organic C (g/kg)	>20	10-20	5-10	< 5
Base saturation (%)	>80	40-80	20-40	< 20

Source. (FAO, 1976).

CL = Clay loam, L = Loam, SL = sandy loam, LS = Loamy sand, LCS = Loamy coarse sand, CS = Coarse sand.

When the texture, pH, effective cation exchange capacity (ECEC) and available phosphorus requirements of yam and cassava were matched with land characteristics of the sites, they were moderately suitable (S2) for the production of both crops.

Table 7. *Suitability Assessment of the Sites for Yam, Cassava and maize.*

	Yam				Cassava				Maize			
Land characteristics/ qualities	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 1	Pedon 2	Pedon 3	Pedon 4
Climate (c)												
Annual Rainfall (mm)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Relative. humidity (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Temp. (^{o}C)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Topography (t)												
Slope (%)	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2
Wetness (w)												
Drainage	S2	S2	S1	S1	S2	S2	S1	S1	S2	S2	S1	S1
Soil physical characteristic (S)												
Texture	S2	S2	S2	S2	S2	S2	S2	S2	S1	S2	S2	S2
Soil depth (cm)	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1	S2
Soil fertility (f)												
pH	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
OC (g/kg)	S3	S3	N1	S3	S3	S3	N1	S3	S3	S3	N1	N1
Av. P (g/kg)	S2	S2	S2	S2	S2	S2	S2	S2	S2	S3	S3	S2
TN (g/kg)	S3	S3	N1	S3	S3	S3	S3	S3	S3	S3	N1	S3
ECEC	S2	S2	S2	S2	S2	S2	S2	S2	S3	S3	N1	S3
BS (%)	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2	S2	S2
Aggregate suitability	S3 (f)	S3 (f)	N1(f)	S3(f)	S3(f)	S3(f)	S3(f)	S3(f)	S3 (f)	S3 (f)	N1(f)	N1(f)

Total nitrogen of all the soils was marginally (S3) suitable with exception of pedon 3 where the nitrogen content is currently not suitable for yam and cassava cultivation. Furthermore, organic carbon made soils of pedon 3 not suitable (N1) while other pedons were marginally suitable for yam and cassava cultivation. Generally, soil fertility (low organic carbon and total nitrogen contents) was a serious constraint to both yam and cassava cultivation in the sites investigated.

Suitability Classification of the Soils for Maize Production

Table 6 showed the land requirement for maize as described by FAO, (1976); Sys et al. (1985). When land requirements of maize were matched with the land quality of the studied soils (Table 1), all the sites were highly suitable (S1) in terms of the climatic requirements for maize production. The topography of sites 1and 2 was favourable while that of sites 3 and 4 was moderately suitable for maize cultivation. Soil drainage made pedons 1 and 2 moderately suitable (S2) and pedons 3 and 4 highly suitable (S1) for maize production. Also, pedon 1 was highly suitable while others were moderately suitable when soil texture of the sites was matched with the soil texture requirement of maize. However, considering the depth of the pedons, pedons 1 and 4 were moderately suitable while pedons 2 and 3 were highly suitable (S1) for maize production (Table 7). The acidic condition of the soils made all the sites moderately suitable for maize production. Currently, considering the organic carbon contents of the soils, sites 1 and 2 are marginally suitable (S3) while sites 3 and 4 are not suitable (N1) for the production of maize. Considering the total nitrogen contents of the different sites investigated, pedon 4 was not suitable while pedons 1, 2 and 3 were marginally suitable for maize cultivation. The phosphorus contents of the sites made site 1 and 4 moderately suitable (S2) and site 2 and 3 marginally suitable for maize production.

Aggregate Suitability Evaluation of Studied Sites

The results of the aggregate suitability ratings showed that sites 1, 2 and 4 are currently marginally (S3) suitable for both yam and cassava cultivation while pedon 3 is not suitable (N1) for yam cultivation. The major land characteristic limiting the cultivation of these crops was soil fertility, which resulted from low organic carbon and total nitrogen contents of the soils (Table 7). For maize, sites 1 and 2 are currently marginal suitable (S3f) while sites 3 and 4 are currently not suitable (N1f) for the cultivation of maize. Generally, the major limitation for the optimum production of cassava, yam and maize in all the sites was soil fertility.

Conclusions

The climatic condition of the sites investigated made the sites highly suitable for yam, cassava and maize production. However, organic carbon and total nitrogen made the sites currently not suitable (N1) for yam, cassava and maize production. For optimum performance of the test crops, proper agronomic practices should be carried out to improve the fertility status of the soils. Organic matter application is also recommended to increase soil cation exchange capacity. As nutrient deficiency and low organic carbon content are the most important limiting factors, it needs to be alleviated so as to sustain crop production in the soils studied. Also, leaching causes big nutrient losses when lime and fertilizers are applied; therefore, heavy applications of these nutrients and of N fertilizers should be split. Organic matter application is also recommended to increase soil cation exchange capacity.

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Phytodiversity and Ecological Aspects Evaluation of Moist Temperate Himalayan Belt, Azad Jammu and Kashmir

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Abstract

To access floristic composition and ecological characteristics, present study was carried out in moist temperate territories of district Bagh. The altitude of the study area varies between 1500 m and 3500 m. Vegetation of the area was mostly therophytic, hemicryptophytic, nanophanerophytic, nanophyllus and microphyllus. Based on IVI twelve plant stands were recognized and all of them were found to be heterogeneous. Environmental factors such as climate, soil condition etc. were studied in relation to vegetation structure. The soil of investigated area varied from heavy loam to clay and clay loam with pH of 5.83 - 7.31 while saturation% age differed from 43 – 62%. Electrical conductivity ranged from 0.8 - 0.21 ds/m, organic matter% age from 3.3 - 6.2, phosphorus from 9 - 21 ppm and potassium from 240 - 412 ppm. The highest recorded Simpson Diversity Index value was 15.67 while lowest was 6.30, species richness was high at an altitude of 2520 m i.e. 1.11 while lowest at 1926 m which was 0.71. Maturity index value lies in between 40.5 - 60.7 while equitability values ranged from 0.66 to 1.63. The present research would serve as baseline information for the future researchers in related fields.

Key words: Phytodiversity, Environmental, Soil, Vegetation.

Introduction

District Bagh of Azad Jammu and Kashmir state lies in the western Himalayas, with varying climatic zones namely sub-tropical, temperate and alpine which exhibits rich floristic diversity. In present study three different sites of this district namely Mehmood Galli, Lasdanna and Bankhori lies between 73° - 75° east and 33° - 36° north with altitudinal variations of 1500 - 3500 meters were phytosciologically investigated (Fig 1). Dogra slates and Murree formation are the major types of rocks while Mahal and Malvani are two main water tributaries within the Bagh sub-division however each individual pocket (Valley) of the area has its own stream, emerging from the mountain springs distributed generously by nature as described by Anonymous 2007.

Plant taxa in any specific geographic site represents flora of that location while assemblages of plant species and the ground cover they provide is termed as vegetation

(Burrows 1990). Hence flora of an area includes number of plant species while vegetation refers to distribution, number and size of individuals (Ali, 2008). Characteristics of vegetation or flora of an area i.e. floristic profile, species distribution, cover, richness and diversity varies particularly with slopes, aspects, environmental condition, soil character, location etc. (Uniyal et al., 2006). Phytosociology or plant sociology is actually floristic diversity estimation and valuation including physiognomies of plant populations via modest and swiftly employs field practices (Rieley and Page, 1990).

Various quantitative phytosociological works has been reported from numerous parts of Pakistan. Some of the most important studies include Qureshi et al. (2009 and 2011), Ahmed et al. (2010), Shaheen et al. (2012), Khan et al. (2013) and Malik et al. (2007 and 2013) etc.

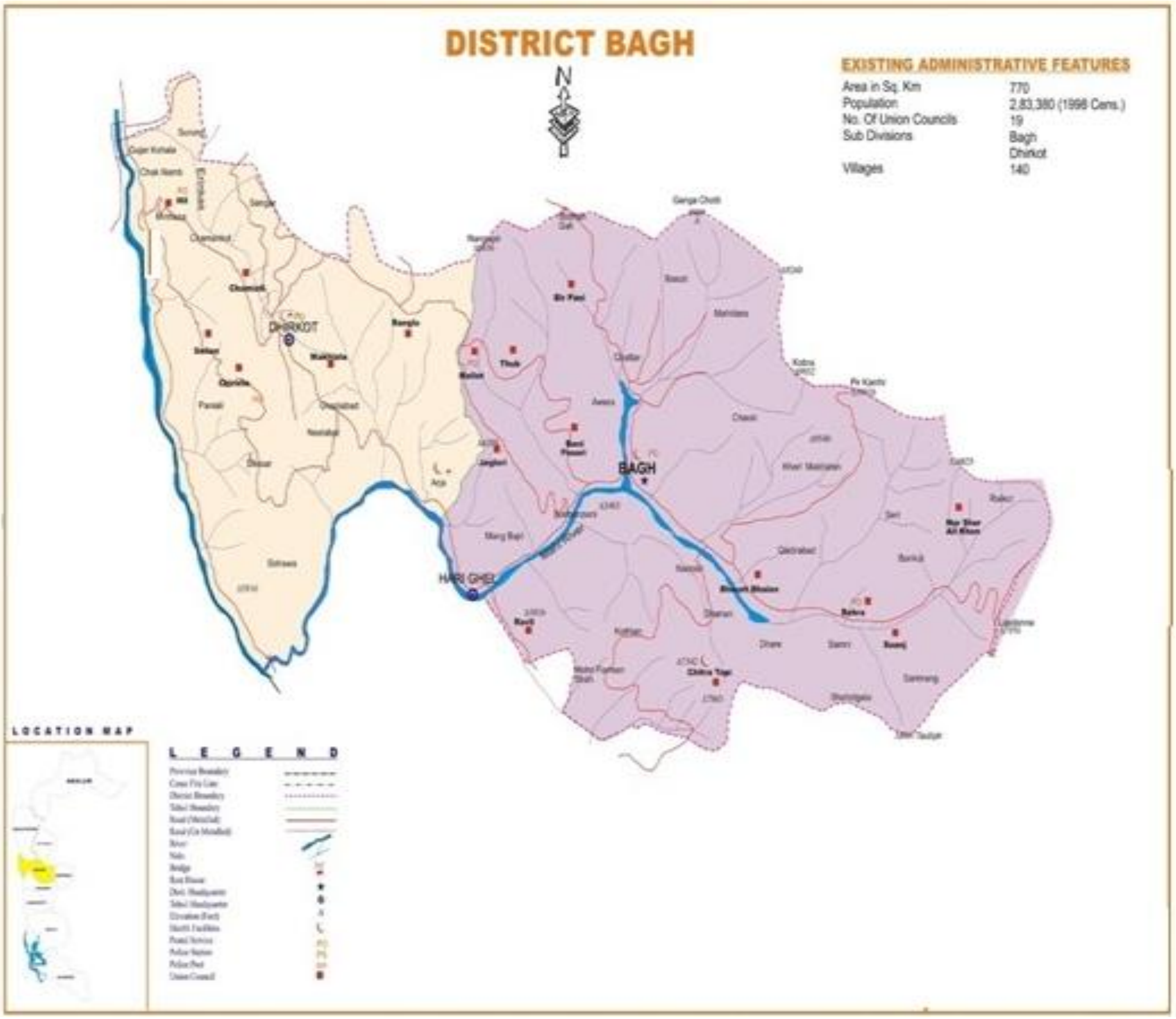

Figure 1. *Map of district Bagh, AJ&K.*

Due to diverse habitats, such as forests, lakes, rivers, tributaries, springs, pastures and sharp altitudinal gradients AJ&K state is well off in phytodiversity. In spite of rigorous floristic and vegetation studies in the AJ&K state including district Bagh, there is still no single comprehensive up-to-date information on the vegetation and biodiversity of Lasdanna, Mehmood Galli and Bankhori. Keeping in view the importance of plants, present study aims to enumerate vegetation by using various phytosciological techniques as done by Shaheen et al. (2011 and 2012) and Qureshi et al. (2009 and 2011).

Materials and Methods

Vegetation data was recorded randomly by using quadrat method during August 2011. The area was divided into twelve stands on the basis of altitude and physiognomic characters. The size of quadrat was 10 × 10 m2 for trees, 5 × 5 m2 for shrubs and 1× 1 m2 for herbs (Amjad et al. 2013). In each stand five quadrats were laid for trees, ten for shrubs, and twenty for herbs. Total quadrats in all the stands were 420 (Malik et al. 2007). Phytosociological attributes viz density, frequency & basal area was calculated, according to the method described Curtis and McIntosh (1950). Importance Value Index (Kent & Coker, 1995) was used to rank each species and the plant species with the highest importance value in the stand was considered the dominant species.

Soil was collected from each site up to 15cm depth and analyzed physico-chemically. The analysis techniques were as follows: total organic matter was determined by using wet combustion method, total potassium by flame photometer, actual acidity by beckman expanded scale pH meter, and phosphorus by olsen method (Dasti & Malik 1998). Physical analysis of soil were done by bouyoucos hydrometer method, and classified according to american soil classification triangle (Champion & Pratt 1961). Phytodiversity of the investigated area was calculated by using Simpson index while components of diversity e.g. species richness, equitability and degree of maturity were calculated by using Menhinick., 1964, Peet., 1974 and Pichi-sermolli’s., 1948 methods respectively. Life form and leaf spectra were recorded by using Mueller Dum Boiss and Ellenberg., 1974 and Raunkiaer., 1934 methods respectively.

Results

Floristic Structure

On the basis of IVI twelve plant communities containing 41 plant species amongst 25 families were recorded from the investigated area. Tree layer comprises of Pinus wallichiana, Quercus baloot, Aesculuc indica, Abies pindrow, Cedrus deodara, Persea duthiei and Lonicera quinquelocularis. Dominant shrubs of the area were Sarcococca saligna, Viburnum grandiflorum, Berberis lyceum, Indigofera heterantha and Rosa brunonii while herb layer, ferns and grasses contained Impatiens edgeworthii, Fragaria nubicola, Onychium japonicum, Dryopteris stewartii, Adiantum venustum, Digitaria cilaris and Cynodon dactylon etc (Table 1).

Table 1. *IVI of the plant species recorded from Mehmood Galli, Bankhori and Lasdanna, district Bagh AJ&K.*

Communities	1	2	3	4	5	6	7	8	9	10	11	12
Tree layer	**IVI**											
Pinus wallichiana. A.B.jackson	48.01	54.71	75.1	60.98	51.74	53.33	32.62	94.78	-	-	-	-
Quercus baloot. Griff	7.60	9.92	7.08	9.16	-	-	-	-	-	-	-	-
Aesculus indica. Wall.ex.camp	-	13.54	12.63	17.87	-	8.16	7.86	8.29	4.17	3.11	3.70	8.27
Persea duthiei. King.ex.Hook	-	-	-	-	8.08	3.21	12.08	13.62	-	-	-	-
Cedrus deodara. Rox.ex.D.Don	-	-	-	-	-	8.04	13.9	-	-	-	-	
Abies pindrow. Royle	-	-	-	-	-	-	-	-	113.8	103.6	115.8	118
Lonicera quinquelocularis. H	-	-	-	-	-	-	-	-	-	-	9.27	8.93
Shrub layer	**IVI**											
Viburnum grandiflorum. Wall.ex.Dc	25.25	24.35	20.63	26.7	-	24.96	20.35	9.96	28.81	23.41	29.16	12.09
Sarcococca saligna. D.Don	20.28	29.75	28.38	22.17	27.3	25.24	24.17	19.9	-	-	-	-
Berberis lycium. Royle	6.98	1.52	6.78	5.09	19.01	10.73	13.93	19.53	29.2	28.62	8.05	12.05
Rosa brunonii. Lindl	-	7.35	3.44	8.2	12.19	3.81	6.18	3.11	-	-	-	-
Indigofera heterantha. L	-	-	-	-	-	-	-	-	-	-	10	16.9
Herb layer	**IVI**											
Viola odorata. L	21.23	12.54	11.26	9.3	4.66	5.79	6.39	7.63	5.58	8.19	12.69	10.49
Dryopteris stewartii. Fess	26.06	25.48	15.31	26.33	31.75	20.94	23.73	14.95	-	-	-	-
Digitaria ciliaris. Roth	38.52	34.71	33.19	26.49	25.14	29.68	37.51	24.7	26.98	29.09	11.75	8.17
Fragaria nubicola. Lindl.ex.Lacaita	15.57	8.83	8.52	7.94	13.9	7.56	8.79	7.59	8.64	9.7	-	-
Myriactis nepalensis. Lessing	11.66	8.31	6.5	5.15	5.07	4.46	8.17	3.57	-	-	-	-
Onychium japonicum. Kunze	47.36	24.33	16.79	21.03	59.59	45.94	34.44	25.14	-	-	-	-
Impatiens edgeworthii. Hook	8.60	7.45	7.52	4.56	6.22	4.9	7.29	5.08	-	-	-	-
Viola biflora. L	12.12	8.67	6.69	5.57	2.7	4.44	7.02	5.74	-	-	-	-

Table 1. *IVI of the plant species recorded from Mehmood Galli, Bankhori and Lasdanna, district Bagh AJ&K. (Continue)*

Anaphalis nepalensis. (Spreng)Hand	10.50	-	5.51	6.33	2.7	6.69	5.31	5.88	-	-	-	-
Bergenia ciliata. Boriss	-	-	-	-	-	-	-	-	6.63	11.9	14.51	10.73
Anemone vitifolea. Buck-Ham	-	-	-	-	-	-	-	-	8.74	5.26	3.81	3.41
Rumex hastatus. D.Don	-	-	-	-	-	-	-	-	17.1	16.26	14.06	16.1
Urtica dioca. L	-	-	-	-	-	-	-	-	6.41	11.9	14.51	10.73
Prunella vulgaris. L	-	-	-	-	-	-	-	-	6.41	5.85	-	-
Stellaria decumbens. Edgeworth	-	-	-	-	-	-	-	-	-	-	2.25	7.54
Adiantum venustum. D.Don.ex.Hook	-	-	-	-	14.16	8.47	14.31	11.52	5.25	10.53	8.88	11.25
Impatiens balsanina. L	-	-	-	-	-	-	-	-	4.83	5.08	7.06	5.88
Geranium nepalensis. Sweet	-	-	-	-	-	-	-	-	4.31	6.76	10.3	11.01
Taraxacum officinale. Weber	-	-	-	-	9.48	7.58	6.39	6.97	9.69	-	5	5.62
Cynodon dactylon. L	-	-	-	-	-	-	-	-	-	-	20.31	19.44
Campanula benthamii. Wall	-	-	-	-	-	-	-	-	5.37	5.26	-	-
Ceterach dalhousiae. Hooker	-	-	-	-	-	-	-	-	2.51	6.59	-	-
Saxifragara androsacea. Dc Sch	-	-	-	-	-	-	-	-	4.31	3.1	-	-
Pteris vitata. L	-	16.58	-	-	-	8.71	3.74	7.63	-	-	-	-
Arisaema flavum. Schott	-	-	-	-	-	-	-	-	0.93	-	-	-
Achilla millefolium. L	-	-	8.44	6.72	-	-	-	-	-	-	-	-
*Arisaema jacquemontii.*Blume	-	11.72	11.77	6.42	6.09	4.9	5.51	4.05	-	-	-	-
Swertia paniculata. Wall	-	-	14.2	14.6	-	-	-	-	-	5.26	-	-
Ranunculus sceleratus. L	-	-	-	9.14	-	-	-	-	-	-	-	-

Climatic Conditions

Climatic data of Bagh was taken as an average of last eight years climatic data of Poonch division. Results indicated that climate of investigated area varies with altitude. The main eastern part was very cold in winters and moderate in summers. Average annual rainfall is 142.9 mm. Maximum rainfall 281.7 mm and 174.6 mm occur during the months of July and August while minimum rainfall 44.5 was recorded in November. June and July were the hottest moths with temperature of 28.45 C° and 27.23 C° whereas December and January were coldest months representing -2.55 C° and -0.86 C° respectively (Fig 2 & 3).

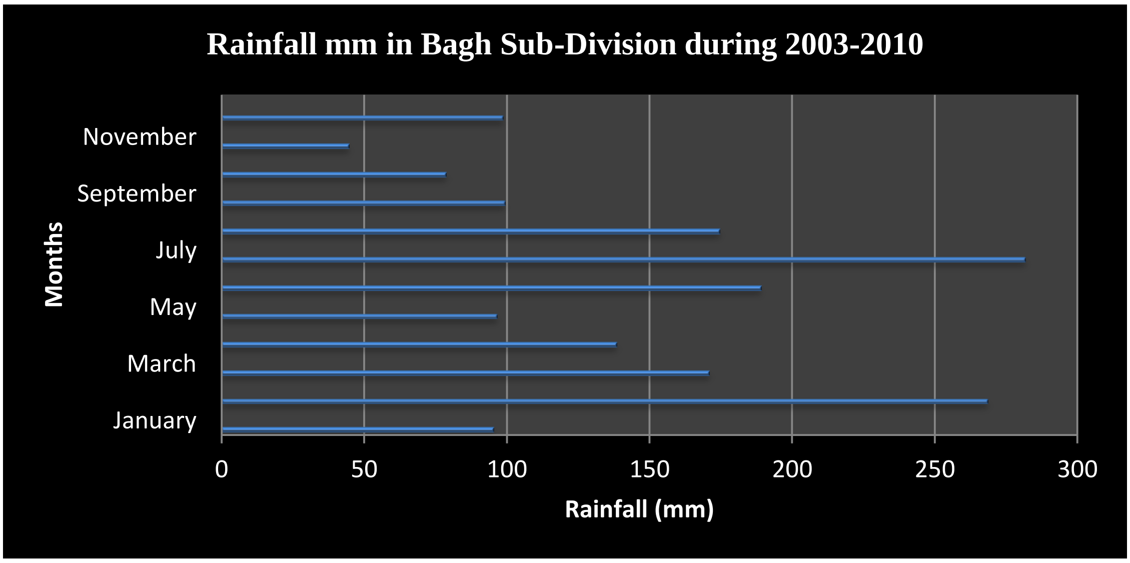

Figure 2. *Graphical representation of recorded rainfall mm in district Bagh AJ&K.*

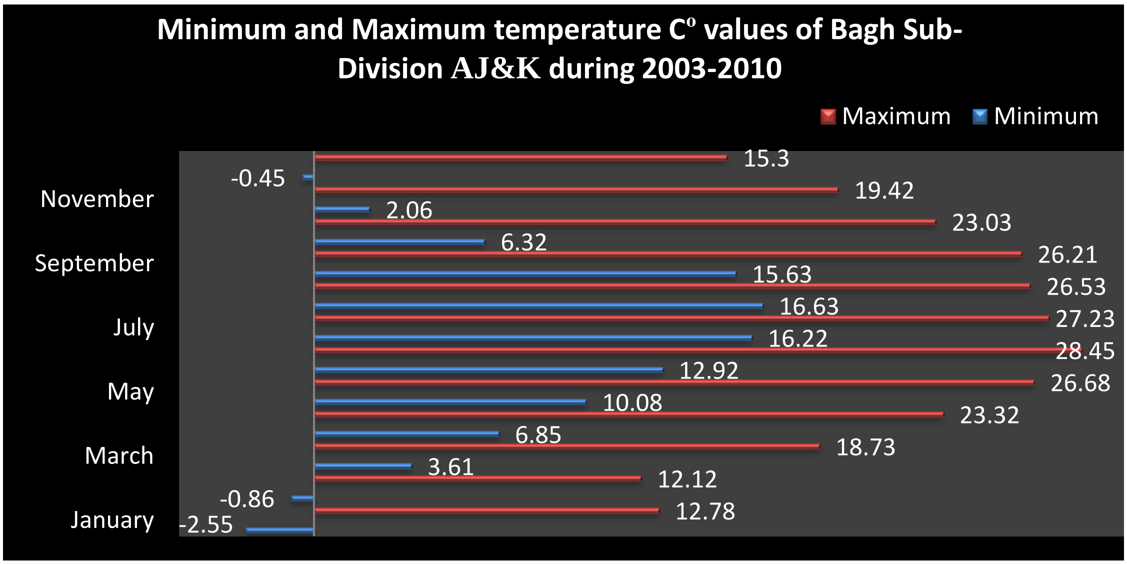

Figure 3. *Graphical representation of recorded temperature C° in district Bagh AJ&K.*

Soil Analysis

Out of twelve investigated stands eight have soil with heavy loam; three have clay loam while only one stand possesses loamy soil. The pH ranges from 5.83 – 7.31; nine sites have acidic pH hence only three sites were with basic pH. The saturation differed from 43% to 64% while electrical conductivity lies in between 0.8 ds/m to 0.21 ds/m in all stands. Organic matter varies from 3.3 – 6.2. Highest contents of potassium were recorded at 2565 m while lowest at 2494 m (Table 2).

Table 2. *Soil Physico-Chemical analysis of the stands recorded from Mehmood Galli, Bankhori and Lasdanna, district Bagh AJ&K.*

Stands	Altitude (m)	E.C ds/m	Saturation %	O.M %	P (ppm)	K (ppm)	pH	Texture
Stand 1	1926	0.12	52	5.0	13	253	6.52	Heavy Loam
Stand 2	2028	0.19	61	3.3	09	309	7.12	Heavy Loam
Stand 3	2132	0.10	44	4.6	15	324	6.89	Loam
Stand 4	2194	0.9	49	4.4	19	312	5.90	Heavy loam
Stand 5	2494	0.13	46	6.0	16	240	6.40	Clay Loam
Stand 6	2520	0.8	56	5.4	12	289	7.23	Heavy Loam
Stand 7	2544	0.11	62	5.9	17	358	6.93	Heavy Loam
Stand 8	2565	0.17	49	6.2	13	412	6.66	Clay Loam
Stand 9	2804	0.15	43	4.8	21	345	6.78	Heavy Loam
Stand 10	2829	0.21	64	5.6	15	401	7.31	Clay Loam
Stand 11	2730	0.14	58	4.9	19	242	5.83	Heavy Loam
Stand 12	2665	0.16	51	6.1	16	295	6.32	Heavy Loam

Biological Spectrum and Leaf Spectra

Concerning biological spectrum based on life forms it was cleared that most of plants in the investigated area were therophytic in nature contributing 29% followed by nanophanerophytes and hemicryptophytes 19% each, geophytes 16%, magaphanerophytes 14% while only 3% were chaemophytes (Fig 4). Leaf spectrum of the vegetation of these twelve stands was dominated by nanophylls flora i.e. 46% followed by microphylls plants 29%, then leptophylls 7% and mesophylls 3% taxa respectively (Fig 5).

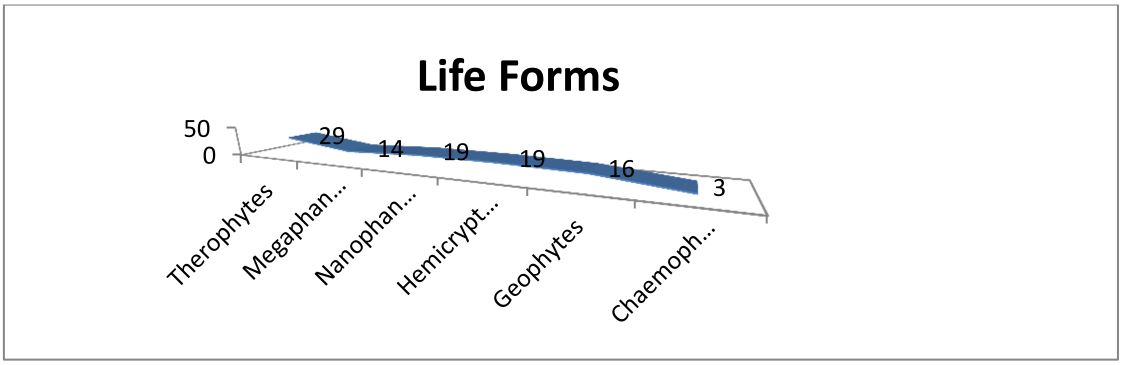

Figure 4. *Biological spectrum based on life forms recorded from district Bagh AJ&K.*

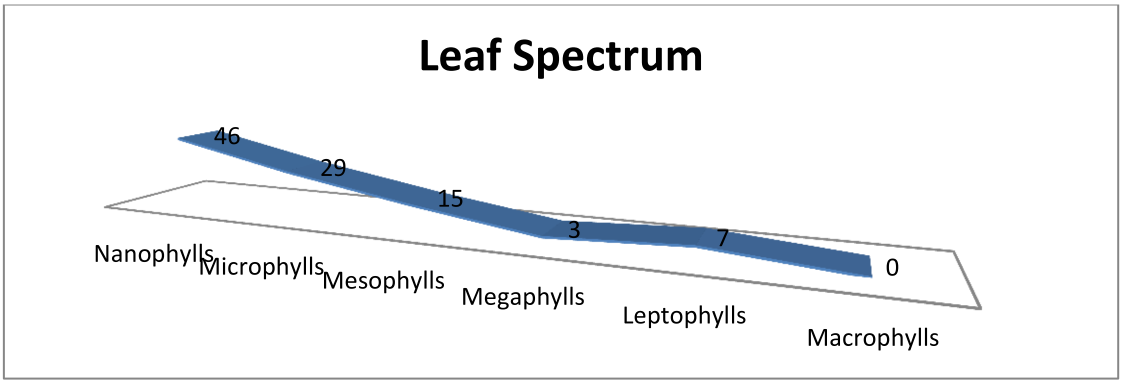

Figure 5. *Leaf spectra recorded from district Bagh AJ&K.*

Diversity and Its Component

Index of diversity and its component recorded from district Bagh, AJ&K are presented in Table 3. The highest diversity value (15.67) was recorded from stand 12 while lowest from stand 5 similarly species richness was high at 2544 m and low at 2494 m respectively. The maximum equitability (1.63) was recorded for stand 12 at the top (2665m) thereafter it decreases up to 0.66 in stand 5 at 2494 m. Maturity index showed that only one community was mature with 60.72% maturity value, while all the remaining communities of the investigated area were immature.

Table 3. *Diversity and its component recorded from district Bagh AJ&K.*

Stands	Altitude (m)	Simpson Diversity	Species Richness	Equitability	Maturity Index
Stand 1	1926	7.92	0.71	0.90	60.72
Stand 2	2028	10.73	0.85	1.14	52.36
Stand 3	2132	12.15	0.97	1.24	48.16
Stand 4	2194	11.88	0.93	1.19	49.50
Stand 5	2494	6.30	0.86	0.66	47.06
Stand 6	2520	8.34	1.11	0.82	40.72
Stand 7	2544	11.48	1.13	1.13	43.58
Stand 8	2565	12.91	1.05	1.29	45.75
Stand 9	2804	12.44	1.08	1.25	40.50
Stand 10	2829	10.46	1.01	1.07	46.58
Stand 11	2730	13.30	1.04	1.38	41.39
Stand 12	2665	15.67	1.08	1.63	44.73

Discussions

Composition and distribution status of plant communities was found to depend on soil components and other environmental factors including, climate, topography, geology and altitudinal range. If there is change in any one, the composition of community will be changed. The relationship between plants and soil are very close and vegetation cover and its component species are reasonably good indicator of soil conditions. Soil provides a foremost reservoir for the collection of water within (Mahmood 2005). Community structure provides data about recognition and definition of different vegetation types; their mapping and the study of relationship between plant species distribution and environmental control. Human interaction moulds the shape and course of succession of a community. Amongst major factors that influenced vegetation structure are human disturbance, extensive grazing, trampling and soil erosion.

The present study area was between 1500 and 3500 m high from sea level. There were twelve plant communities in monson season. The communities recorded in present study actually reflected various remnants; degraded stages of major vegetational unit as identified by Champion et al. 1965; Beg 1984 & Malik 2005. The upper most stratum was dominated by Pinus wallichiana, Abies pindrow, Quercus baloot, Aesculus indica, Persea duthiei, Cedrus deodara and Lonicera quinquelocularis while the middle stratum of shrubs was dominated by Berberis lycium, Indigofera heterantha, Viburnum grandiflorum, Sarcococca saligna and Rosa brunonii at different elevations and aspects. The herb layer contained Dryopteris stewartii, Digitaria ciliaris, Onychium japonicum and Cynodon dactylon as dominant species. With slight deviation the present findings are in line with those of Ahmad & Qadir 1976; Malik et al. 2001; Shaheen et al. 2011.

The distribution and composition of plant communities in the surveyed area seem to be controlled by a complex of environmental factors including climate, topography, soil and biotic influence. These all undergo changes of different degrees due to their own interactions and may result in micro-gradients Ahmed et al. 2010. Soil characteristics influence plant distribution on smaller scale i.e. more local scale Siddiqui et al. 2009. Topography and different altitudes are main factors that play important role in structural characteristics of vegetation and support different communities in district Bagh. The main biotic and anthropogenic factors influencing the vegetation of district Bagh are the deforestation, unnecessary uproot of medicinal plants and overgrazing. The biotic interference completely upsets the natural process of interaction between climatic, edaphic and topographic factors to control growth and occurrence of individuals and results in quite an unpredictable pattern of vegetation distribution (Wahab et al., 2008). The species composition as well as vegetation patterns are mainly determined by man’s impact and only to a minor extent by natural site factors Haider & Qaiser 2009; Hussain & Ilahi 1991; Mughal, 2006).

Conclusion

The present study indicated that district Bagh has great potentialities for plant biodiversity conservation in the form of ecosystem diversity, species diversity and genetic diversity. If the anthropogenic and other biotic interferences continue in the area at present pace, the valuable bio resources of the area may be wasted and lost soon Hussain et al. 1994. The area needs proper attention by government agencies, naturalists and nongovernmental organizations for protection, management, sustainable use and improvement. Any effort directed for improving the area cannot be successful without the cooperation and involvement of local inhabitants. The indigenous people have a comprehensive ability to recognize, classify, name and perceive nature that lead them to understand the ecology, reproductive biology and uses of organism in their ecosystem Connor, 2007; Akhani & Ziegler 2002. Thus it is suggested that the conservation of plant biodiversity should be considered as integral needs in the process of development today Noroozi et al. 2008. If handled with a true spirit, the improvement of the forest resources of district Bagh will not only improve the socioeconomic condition of the present people but will also serve as a valuable gift for generations to come.

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